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SOCIETY OF EDINBURGH, OF THE ROYAL ACADEMY OF SCIENCES
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BY

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Dr Jas. M. Rice

Jas. F. M. Rice

Jas. F. M. Rice

William Rice

Jas. F. M. Rice

LECTURES

As. H. M. Ree Jun
CHEMISTRY. 1839

As. L. M. Ree

Wells

CLASS III.—CONTINUED.

CHARCOAL is the fourth kind of inflammable matter which I enumerated, and which deserves a separate consideration.

What is commonly called charcoal, is not produced by nature; though there are native inflammable substances which approach to it nearly by their qualities and constituent parts. But they are known by other names. What is commonly meant by this term is artificial, and produced from wood, by burning it, or rather scorching it with a smothered fire, until it be red hot, and then stopping the further progress of combustion, by covering it so closely as to exclude completely the further action of the air.*

This process is practised, as I said, with wood only, when we wish to prepare what is commonly called *charcoal*, which is employed in refining iron, preparing steel, &c. But a similar product may be obtained, by similar treatment, from all vegetable and animal substances, and from the bitumens; all of which, if heated gradually until all their volatile matter is expelled, and with proper precaution to prevent inflammation, will afford charcoals. Such is the charcoal from pit-coal, called COAKS. Small pieces of charcoal may be finely prepared for

* Vide Les Arts et Metiers, CHARBON.

experiments, by plunging a piece of hard wood into red hot lead, and keeping it there till all ebullition or eruption of vapours of any kind is over; or by putting it into a crucible with good sand, and luting on a cover, to prevent all action of the air, and then keeping this for an hour or more in a red heat. Dr. Priestley observes, that charcoal, which is made with extreme slowness, retains much inflammable matter, which a hasty operation dissipates in vapour; and that, after it has so retained it, no heat can afterwards dissipate it in close vessels.

All these substances from which charcoal can be prepared, contain a considerable proportion of inflammable matter. Their other constituent parts are a small portion of earth and salts, and a large quantity of water. By the action of the smothered heat, the water is dissipated, partly alone, in watery steams, partly combined with other matters, in oily or sooty vapours, which are still very inflammable. But a particular kind of the inflammable matter remains united with the earth and the more fixed salts; and with these constitutes the charcoal that is at present to occupy our attention.

Charcoal is always black and opaque; and, if produced from a solid substance, such as wood, bone, or the like, generally retains the external form, and some appearance of the organic structure of the mass from which it was produced.

Charcoal thus formed is distinguished among the inflammables by several remarkable and peculiar qualities:

1st, When we expose it to the action of heat alone, and take care that all access of fresh air to it be effectually prevented, it appears to be perfectly fixed and unalterable by heat. The utmost violence of heat applied in this manner has no power either to melt it or to volatilize it. Dr. Priestley, it is true, thought that he had converted charcoal totally into a species of inflammable air by the action of heat alone. He made the experiment by placing the charcoal in the vacuum of an air-pump, and directing the focus of a burning glass on it. But there is great reason to suspect that this effect was not produced by the action of heat alone, but by that of heat and watery vapour applied at the same time to charcoal. That watery vapour, assisted with a red heat, very quickly consumes and volatilizes

charcoal, is now very certain, from the experiments of Mr. Lavoisier, Dr. Priestley, and others; viz. those already mentioned, which were made by pushing the steam of the water through a red hot tube, in which different substances were exposed to its action. When the experiment was made with charcoal, it was attended by the production of hydrogen gas and carbonic acid. *This* hydrogen gas from charcoal contains some charcoal dissolved in it; and being thereby heavier than pure hydrogen gas, it is named by some authors *heavy inflammable air*, by others, *carbonated hydrogen*.

Mr. Lavoisier is of opinion that the charcoal is only dissolved on this occasion, but not, properly speaking, decomposed. He thinks that it is the watery vapour which is decomposed, and supplies the hydrogen gas, the charcoal joining with the oxygenous principle, or basis of vital air, which the water contains, and being thereby dissolved and converted into carbonic acid. We have not, therefore, as yet, any proof that charcoal can be volatilized by the action of heat alone, unless we reckon on some light black powder obtained in distillations of sulphuric acid from inflammable substances.

As charcoal suffers no change from the most violent action of heat alone: so it does equally resist the powers of the air and humidity when these are not aided by heat. It is a common practice to scorch the ends of stakes which are to be driven into the ground, that they may be less liable to rot and decay: and this is done with considerable success. They become thereby a great deal more durable*. But when wood is perfectly charred, we have no experience of any end to its duration. It is totally exempted from any change or decay to which so many other substances are liable by the long continued action of the elements on them.

* About forty years ago, a number of pointed oak stakes were discovered in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent Julius Cæsar from passing his army over by that ford. They were all charred to a considerable depth, and retained their form completely: and were so firm at the heart, that a vast number of knife-handles were manufactured from them, and sold as antiques, at a high price....EDITOR.

6 CHARCOAL VERY INDESTRUCTIBLE.

The knowledge of this incorruptibility of charcoal has given occasion to a most useful contrivance, which has been lately thought of, for preserving water uncorrupted at sea. Water at sea corrupts, in consequence of its drawing a tincture, or dissolved matter, from the wood of the cask, which dissolved matter is a very corruptible substance. But it has been lately contrived to burn or sear the internal surface of the cask with flame or hot irons, until that internal surface is changed into charcoal, after which it no longer yields any corruptible matter to the water.

Charcoal equally resists the most powerful and destructive solvents. Those which tear into atoms the metals themselves have not the least effect on it so long as the charcoal remains cold. It is only by being heated that it becomes liable to the action of various bodies. In its hot state, all those substances which are disposed to act remarkably on the inflammable bodies in general shew that they have the same power on charcoal. Such are the sulphuric acid, the nitric acid, nitre, the phosphoric acid, calces of metals, and the vapour of water. *Hepar sulphuris* has also the power to dissolve charcoal.

When a pound of sulphuric acid was distilled with half an ounce of charcoal, the charcoal was totally dissolved, and it changed a part of the acid into sulphurous acid. The liquor became of a sea-green colour, which disappeared when the liquor was cooled, and returned when it was again heated. A greater portion of charcoal produces sulphur, by distillation. The operation is extremely troublesome,....the production of sulphur very partial: and a great part of the charcoal is volatilized, in the form of an impalpable powder, which collects in the neck of the retort, and often chokes it up. The distillation may be repeated again and again with the volatilized acid and charcoal, and always produces the most intolerable suffocating fumes: but the colour at length disappears. It also deserves remark, that both the sulphur and the volatilized charcoal appear before any considerable quantity of the acid has come over.

Nitric acid also acts remarkably on dry charcoal, when very strong. When the mixture takes place properly, it bursts out into a flame. In all cases, the charcoal decomposes

much of the acid, by depriving it of oxygen, and we obtain nitrous gas and carbonic acid.

We have already seen the effect of the acid of phosphorus on charcoal. It is decomposed by the charcoal, and we obtain phosphorus and carbonic acid; which last must be allowed to escape.

It dissolves in hepar sulphuris both in the humid and dry way, rendering it of a much deeper colour. In the dry way, charcoal combined in a very great proportion, produces very singular effects. To produce this combination, however, in the best manner, the sulphur must be taken red hot, in its nascent state, as in the process for producing sulphur *de novo*, by treating charcoal in a red heat with a vitriolic salt. In this compound, the united attractions of both the sulphur and the charcoal for oxygen produces such a rapid combination and heat, that the mixture takes fire when exposed to the air. Such mixtures are therefore called *pyrophori*. I shall conclude this article with a particular account of them.

As heat disposes charcoal to be attacked and decomposed by these substances, so does it also prepare and dispose it to be acted on by the air. You all know that the consequence of heating it red hot in the open air, is an immediate beginning of its inflammation, during which it is gradually consumed, and a great deal of heat is produced. The apparent quantity of the uninflamable matter into which the charcoal is changed, or which remains in its place when the inflammation is completed, is very small indeed, when compared with the quantity of the charcoal before it was inflamed. It is only one-ninth of its weight. But this appearance is a deceitful one. There is a much greater quantity of uninflamable matter produced; but it assumes an elastic aerial form, and is diffused in the atmosphere imperceptible to the sight. It is fixed air, or the carbonic acid gas, the total weight of which far exceeds the weight of the charcoal that has been consumed. We can collect and condense this gas, so as to reduce it to a more perceptible form, by the attraction of caustic alkalis or quicklime. And there are other ways by which we can render it perceptible, and estimate the quantity of it. When this is done with exactness, the weight of it is always found equal to the joint weights of

the consumed charcoal and that of the oxygen gas expended in consuming it, and changed along with it into carbonic acid gas. Mr. Lavoisier, by a very careful measurement, found that 100 parts, by weight, of carbonic acid, contain nearly 72 parts of oxygen, and 28 of charry matter.

We have an example of this in the deflagration of charcoal with nitre. You remember what a blowing noise, and succession of explosions, accompanies that deflagration. Curiosity to learn what happens on this occasion, and what was the cause of the astonishing force of gunpowder, suggested a contrivance to fire some of it, or a mixture of charcoal and nitre, in a strong pistol barrel, the end of which was soldered close, and the touch-hole screwed up. And the quantity of materials fired at once being but very small, there was no report or explosion; the strength of the machine being sufficient to confine the flame and elastic matter. The only external sign of the firing of the powder or composition was, that the barrel became hot. It was allowed to cool, and then opened under water, by unscrewing the touch-hole. A quantity of elastic aerial matter came out, which was surprisingly great when compared with the quantity of charcoal and nitre which had been fired. This experiment was made by Mr. Robins, Engineer to the Honourable East-India Company.

But others having repeated it since the nature of the aerial fluids became a subject of inquiry, they found that the elastic aerial matter produced by charcoal and nitre is a mixture of carbonic acid gas and of azotic gas.

Knowing, as we now do, that nitrous acid is composed of seven parts of oxygen, and three parts of azote nearly, we are enabled to explain very clearly the production of azotic gas during the deflagration of charcoal with nitre. And the other experiments which have been described to you explain the production of carbonic acid at the same time. It appears, that the charcoal when heated, acts by a powerful attraction for the oxygen, which abounds in the nitric acid. By uniting, they form the carbonic acid. The other principle of the nitric acid, the azotic gas, is thus set at liberty, and being added to the fixed air, makes up that great quantity of elastic aerial matter which is disengaged from charcoal and nitre.

There is another production sometimes obtained from this deflagration, viz. a very small quantity of volatile alkali. This is explained by another late discovery which I already mentioned, concerning the component principles of the volatile alkali, which is now supposed to be a compound of hydrogen and azote. This being admitted, we can account for the formation of a small quantity of it from some of the mixtures of charcoal and nitre. Some part of the water or humidity inherent in charcoal, and in nitre crystals, is decomposed during the heat of deflagration, by the attraction of the charcoal for the oxygen of the water. Thus the other principle of the water, the hydrogen, is let loose, and, joining with a part of the azote, forms the volatile alkali. This, however, is in this case an accidental production, in small quantity only, and not always perceptible. A chemist in Birmingham, whose name I do not recollect at present, forms volatile alkali in abundance, by passing common air over a mixture of charcoal and vitriolic salts with an earthy basis (such as alum, or Epsom salt) made red hot.

After this explication of the deflagration of nitre with charcoal, I may so far take notice of the deflagration of the same salt with sulphur, as to remark that the products of that deflagration are accounted for by the same principles. The products of the deflagration of nitre and sulphur, are sulphuric acid, formed by the union of the sulphur with the oxygen of the nitric acid, and azotic gas, formed of the azote of the nitric acid and latent heat. The sulphuric acid, the moment it is formed, joins itself to the alkali of the nitre, so that very little of it is volatilized.

By the same inestimable discovery of Mr. Cavendish, by which we first learned the constitution of nitrous acid, we can also account for what happens in the operation by which the largest possible quantity of vital air may be extracted from nitre. In that operation, the nitre is exposed to the action of heat in a small retort of earthen ware, or of glass well coated with clay and sand, and which has a long neck. Sometimes an iron retort or gun-barrel is used; but it is not so proper. The retort is exposed to the immediate contact or action of the burning fuel, but heated gradually in the beginning. As soon as the retort and nitre begin to be

ignited, the vital air begins to come forth. At the first it is very pure, provided the nitre be quite free from dust or admixture of vegetable or animal matter. If such matter be present in it, though in exceedingly small quantity, some carbonic acid gas is formed at first, and comes out mixed with the first portions of vital air and some azote. After this, or from the beginning, if the nitre was quite pure, we obtain a great quantity of good vital air, which, if not quite pure, contains a small admixture of azotic gas. But towards the end of the operation, when the heat must be increased to a higher degree, the vital air comes over mixed with a more considerable portion of azotic gas. The reason of this difference in the purity of the vital air is, that in the beginning, the nitric acid gives out only a part of the oxygen which it contains, (nearly $\frac{70}{100}$) and it is changed into nitrous acid, retaining perhaps $\frac{65}{100}$, and in this state continues adhering to the alkalis. In the nitrous acid, therefore, there is a deficient proportion of oxygen, and a superfluous quantity of azote. When the process is continued, and the heat increased to produce a more complete decomposition of the acid, the azote must necessarily make its appearance in a proportion continually increasing.

All these facts, and many more, to be mentioned as we proceed, and which are so well explained by Mr. Cavendish's discovery, confirm the solidity of that discovery, making it one of the most important which the modern chemistry has produced.

One of the most remarkable properties of charcoal, when recently taken from the fire, is an attraction for a certain quantity of humidity, and for various odorous and colouring matters of different fluids, containing animal or vegetable substances, subject to fermentation or corruption, as also for the acetous acid.

We have proofs of its attraction for humidity in many curious experiments of Dr. Scheele and Dr. Priestley. Although indestructible by heat in close vessels without addition, yet, if moistened, it will yield carbonic acid and hydrogenous gas. This may be repeated by another moistening; and so on, till it is all expended in these productions. This is evidently owing to its strong attraction for oxygen,

in which it exceeds all substances yet examined. It decomposes the water,...combining with the oxygen, and thus forming carbonic acid, and thus also leaving the hydrogen at liberty.

Its action on odorous effluvia is no less remarkable. If laid (fresh made) on silk or linen gummed or oiled for umbrellas, a preparation which continues to exhale a heavy sickening smell for many years, it will remove it in a few hours. It sweetens bilge water, and all kind of corruption that is accompanied with emission of hepatic ammonia. It clears saline solutions of their colouring matter and rank smells, causing them to crystallize in snow-white purity; and is much used for this purpose in pharmacy; as in the preparation of the *terra foliata tartari*, which was formerly a tedious process, and considered as a test of pharmaceutical dexterity. It removes in an instant the heavy flavour of corn spirits hastily distilled. It clears foul camphor in the sublimation from all fuliginous taints. It sweetens water which has grown putrid by long keeping. It even sweetens meat which has already putrified to a very great degree. Mr. Cappe at Lille has published valuable experiments on this subject,...as has also Mr. Lowitz an eminent chemist at Petersburg in Russia. Charcoal is therefore an excellent dentrifice, as very well adapted to the mechanical operation of cleansing the teeth, and still more as the most powerful corrector of all putrescence, which is the chief cause of all disorders of the teeth and gums.

The acting principle in these effects is not yet distinctly understood. As they are generally accompanied by an immediate and great increase of the offensive smells, we are led to ascribe its efficacy to its attraction for oxygen, by which most of those gases are set at liberty.

Powdered charcoal clears water impregnated with carbonic acid so completely that it no more renders lime-water milky.

Charcoal is found to act powerfully in relieving from the pain of heartburn.

In consequence of its strong attraction for pure acetous acid, it becomes a powerful agent for concentrating it by distillation. We are indebted for this, as well as for the full confirmation of the last mentioned chemical property of

charcoal, to Mr. Lowitz. After having concentrated this acid as much as possible by freezing, he mixed it with a great proportion of charcoal fresh made, and distilled it till the charcoal was seemingly dry ; then, changing his receiver, he obtained from this charcoal acetous acid, in the utmost state of concentration and purity, and which crystallized in a cold little below that of freezing water. This is somewhat of an anomalous fact ; because charcoal exhibits no remarkable attraction for acetous acid in a less concentrated state.

I have already observed, that charcoal attracts oxygen more powerfully than any other substance does that we are acquainted with. We cannot decompose carbonic acid by any single elective attraction. Charcoal is employed for separating it from all other bodies. And, in consequence of this power, charcoal is the great instrument in all metallurgic operations ; and in all operations by which we restore to bodies their quality of inflammability. For inflammability is destroyed only by attracting oxygen from the atmosphere, and becoming saturated with it. I have already mentioned the ingenious process by which Mr. Tenant effected the decomposition of the carbonic acid, by means of phosphorus and an alkaline substance.

From all that has been said of charcoal, you perceive that there is a principle common to every combustible substance procured by charring combustible bodies ; and that this principle is exceedingly subtle, since it is found to compose so pure a fluid as carbonic acid, or fixed air. You now see, that although the black substance obtained by the smothered burning of many bodies be solely the production of art, yet the common principle, the *carbon*, so called to distinguish it from the grosser body in which it is found, is one of the most copious and uniform productions of nature. The calcareous, and other absorbent earths, must now be added to the numerous classes of bodies that contain it. And we must, in short, consider every thing as an ore or matrix of carbon, which contains fixed air, or which produces fixed air by union with oxygen.

It is remarkable that a principle so abundant in nature should never be seen in its native form, pure and unmixed. But this arises from its activity and disposition to combine with almost

every substance in nature. The wonderful changes of external appearance which may be induced by such combinations, are now so familiar to you, that although you may be surprised, you will not be disposed to doubt, when I venture to say that in all probability the native, unmixed, form of carbon, is what is known to the world under the name of the DIAMOND! Surely nothing can be more unlike than the most brilliant, the most transparent of all bodies, to a substance essentially black, and completely impervious to light. You will be eager to know the evidence on which I venture such an unlooked-for opinion.

When considering the siliceous earths, I observed that quartz, crystal, and others abounding in them, were distinguished from the rest by several peculiarities. A remarkable smell when they are rubbed together; the light which their friction produces; several appearances of elastic matter issuing from them in their union with fixed alkalis; and their refusal to unite with other siliceous earths, were considered by many chemists, and particularly by the Chevalier Dolomieu, as indications of inflammable matter in them.

The diamond, besides these qualities, is farther distinguished by being totally dissipated by a violent heat; but this only when exposed to the joint action of heat and air. Till the necessity of this combination was discovered, the dissipation of diamond was considered as analogous to the decrepitation of salt, and of many fossils, which may be dispersed by heat in small fragments, which in some cases are even a fine powder. But these fragments could always be collected; whereas the diamond disappears altogether. It has long been suspected, therefore, to be inflammable.

Accordingly, several chemists have lately examined it with the express view of ascertaining this point. Crucibles of fine porcelain, having ground stoppers of the same substance, were employed; and it was found that only a part of the diamond could be evaporated in this way; so much the more, as the vessels contained more air. When covered with the powder of charcoal in the crucible, no change whatever was produced by the most intense heats. When so heated in free air, it gradually consumed, and was all the while of a dazzling brightness,

much more brilliant than the capsule on which it was lying. Although there may be some impropriety in saying that diamond is inflammable, like oils, yet it appears to be combustible like charcoal. Count Sternberge, a gentleman in Bohemia, burnt a diamond in oxygen gas, by fixing to the point of it a bit of iron wire, which he made red hot, and then plunged the whole into a vessel containing vital air. The wire burned with great splendour and production of heat: and this being communicated to the diamond, it took fire and burned in the same manner. The experiment was repeated in a glass vessel, whose inside was moistened with lime-water. It very soon became dim, and was totally obscured, so that the progress of the combustion could not be observed. But this gave strong indication of the presence of carbon in the diamond.

Mr. Smithson Tenant mixed $2\frac{1}{2}$ grains of diamond dust with one-fourth ounce of nitre cleared of the water of crystallization, and exposed the mixture in a tube or retort of gold. A good deal of nitric acid was disengaged before the nitre began to act on the diamond. By this circumstance, the carbonic gas, produced by the action of the oxygen in the instant of decomposition, was absorbed by the fixed alkali, for which it has a strong attraction, and it was all retained. This was obtained by dissolving in water, and adding muriatic acid, which formed a digestive salt, and precipitated a crude calcareous earth, and thus gave Mr. Tenant hold of the carbonic acid. He found this calcareous earth to contain $9\frac{1}{7}$ grains of carbonic acid. By Mr. Lavoisier's repeated examination of the proportion of ingredients in this acid, he found that it held $2\frac{1}{2}$ grains of carbon, which is precisely the weight of the diamond employed.

By this ingenious experiment, which has been repeated both in London and Paris, we seem entitled to conclude that diamond is carbon in a crystalline form.

Another experiment leading to the same conclusion, has lately been made by Mr. Guyton de Morveau. He exposed to an hour's intense heat, a diamond inclosed in a tube of iron, put into a crucible, and surrounded with a mixture of siliceous and argillaceous matter, which had been burnt in a burnt clay crucible. This crucible was inclosed in another, which was coat-

ed with a similar composition. The diamond vanished entirely, though the tube had no aperture: and the inside of the tube was converted into perfect steel. You will afterwards learn that this change is produced by the union of iron and carbon. You see the propriety of Mr. Morveau's precaution to cut off all communication from the fuel to the tube.

The diamond burns at a much lower heat when mixed with nitre, than by any other treatment. When merely heated in contact with atmospheric air, a very strong red heat is necessary to induce that bright shining, which is the indication of its uniting with oxygen, or of burning. When this is done in pure oxygen, the combustion begins a little sooner,...but when mixed with nitre, the combination begins with the lowest red heat. Mr. Tenant found that common charcoal may be rendered extremely hard, so as to scratch and work upon tempered steel, by long continued ignition in close vessels; and that by this treatment its tendency to combustion is so much repressed, that it does not begin to burn till red hot. There are some very remarkable examples of this kind which have lately come to my knowledge. In the dreadful eruption of lava in Iceland, trees growing in crevices of the rocks have been buried under the melted lava, and there charred and covered with melted matter, which has not ceased to be red hot for more than two years. Fragments of these are sometimes brought into view by the convulsions and shatterings of subsequent eruptions, and are called *svaërt souterbrant*. Some pieces of them in my possession require a full red heat for their combustion, and they are totally consumed. I have observed the same thing in a native coak, lately discovered near Newcastle, which has been produced by the protrusion of a mass of melted whinstone, which now forms a dyke in the strata, and it has charred above two fathoms of the seams on each side.

Appendix.....Pyrophori.

I conclude this article with the account of a very curious class of chemical preparations, which derive their distinguishing properties from charcoal. They are called PYROPHORI, because they

are always in a disposition to take fire and burn whenever they are exposed to the free air. They are as commonly, but with less propriety, known by the name of *phosphori*,...*light bearers*, because they have this resemblance to Brandt's phosphorus of urine. They are distinguished, however, by the name of *Homberg's phosphorus*, or *phosphorus of alum*.

This is generally a blackish or dark coloured powder, like charcoal, or the half burnt ashes of combustible bodies. It is kept in bottles well corked. And if a quantity be poured out into the air, especially if the air be a little damp and warm, it grows hot, smokes, and presently takes fire, burning like as much charcoal, with a disagreeable smell.

This phosphorus of Homberg is prepared by first roasting a quantity of meal or flour of any kind, till it is almost charred, taking care that it be not completely so. This charry powder is mixed with a quantity of alum, deprived of its water of crystallization; and the mixture is put into a phial, so as nearly to fill it. The phial is set among sand in a crucible. The sand must surround the phial as far up as it is filled with the powder. The whole is kept in a moderately hot fire, till all fumes have ceased, and a very faint flame, like that of sulphur, has continued for some time. It is now removed, and the mouth of the phial stopped with a cork as soon as it is cool enough to allow it.

When a little of this powder is shaken out of the phial, and formed into a heap, it grows hot, smokes, smelling strongly of *hepar sulphuris*, and then takes fire, if well prepared. If much over or under calcined, it is apt to fail; and it is generally in its best state when it has something of a dirty green colour mixed with it, as if it contained powder of sulphur.

Subsequent experiments and observations have shewn that any salt which contains the sulphuric acid will do as well as alum for the preparation of this pyrophorus. Scheele obtained the finest from vitriolated tartar, or sulphat of potash. Nay, the natural productions, gypsum, fluor, and others, formed by the same acid will answer. We know that all such compounds, when treated with combustible bodies in a strong heat, produce sulphur or *hepar sulphuris*. These pyrophori may therefore be called *sulphureous pyrophori*, or perhaps *hepatic*.

pyrophori. Dr. Scheele* has observed that the steams of hepar sulphuris generate much heat when they absorb vital air. It is very probable that the copious absorption in the present case (for it is very copious) may produce enough to kindle the mixture of nascent sulphur and charcoal.

This substance has not yet been examined with the attention which it deserves ; and we are not yet well assured of the procedure of nature in its inflammation. Mr. Lavoisier has bestowed particular attention on compounds nearly allied to it, in his first essays, published in 1777, and also in his subsequent papers.

There are many other substances which take fire of themselves, by the heat produced in the mutual action of their ingredients. Of this we have already seen an example in the mixture of nitric acid with essential oils ; also with phosphorus. We know that the same thing happens in many cases, where vegetable or animal substances are heaped together in a moist state. They ferment, grow hot, and frequently burn, or at least are reduced to ashes. We shall have occasion to take notice of some remarkable examples of this kind, as we proceed in our examination of inflammable bodies.

At present, I propose to bestow a little attention on another class of bodies known by the name of PHOSPHORI, and to which that name does more peculiarly belong. These bodies do not take fire, that is, do not suffer a decomposition of their parts, accompanied with the production of heat and light. The bodies I now mean to consider only shine in the dark, but without any sensible heat. And they acquire this faculty, not immediately by exposing them to the action of the air, but to that of a strong light.

Of these there is a class very nearly allied to the substance I have last described, by its composition and chemical properties. The most remarkable of them, and the first observed, is that called the *Bolognan phosphorus*,...the *Bolognan stone*, because first found in the neighbourhood of Bologna, about the year 1630, by one Cascarioli (a shoemaker I believe) who observed, that when taken from the light into a dark place, it

continued to shine for some time. As soon as this was publicly known, several philosophers of that time examined the appearances with more care. It was found that two or three seconds exposition to the light was sufficient to make it shine, and that longer exposure did not increase its luminousness. It shone for four or five minutes, and some fine pieces shone for a quarter of an hour. The light of the sun was the most effectual. After this the clear light of day. Nay, the light of a torch made it shine. Moon light had no effect. The light emitted was enough to make the smallest print legible, when held very near.

These facts attracted much attention, and were very interesting to the philosophers of last century, who were at that time much divided in their opinions concerning the nature of light. Some imagined, with the vulgar, and with the followers of Newton, that light was a material emanation from the luminous body; while others, with Des Cartes at their head, imagined that light, or vision, was the effect of a tremulous motion of an elastic fluid, as sound, or hearing, is the effect of the tremulous motion of elastic air. The first class drew strong arguments in support of their opinion from the phenomena of this stone, for it seems to imbibe the light to which it is exposed, and afterwards to give it out again.

It is somewhat singular that so curious a phenomenon did not engage the chemists of that age in a very minute examination of the constitution or ingredients of the Bolognan stone, and cause them to speculate about the way in which it produced those effects. This inquiry was more strongly suggested to them by the methods which must be taken to make the stone a powerful phosphorus. It must be beaten to fine powder, and then made into a paste with water and oil, and then calcined. But it lay a half century neglected; till, in 1675, Baldwin, a German chemist, observed that the residuum from the distillation of the nitrat of lime imbibed the light and emitted it in the same manner; and in 1698, Homberg discovered the same thing in the Muriat of lime; and in 1730, Dusay found that many other substances, when calcined in the same way, had the same property. A series of curious observations of this kind by Beccaria (Giacomo Bartholomeo) greatly augmented

this list. But although these discoveries naturally occasioned some chemical examination of the Bolognan stone and calcined phosphori, no addition of knowledge was obtained, till Mr. Margraaf examined them with his accustomed skill, in 1749. He found that the Bolognan stone was a sort of gypsum, or a heavy spar, containing the sulphuric acid united to calcareous earth. Subsequent observations, however, prove it to be a barytes united to that acid. He found that all heavy spars could be made phosphorescent by proper calcination., Leibnitz made the same observation in the first vol. of the *Miscell. Berol.* with respect to fluor. Margraaf gives the manner of preparing those substances in the best manner, viz. by pulverizing, and then making the powder into small cakes with a little gum water, then drying them slowly, and calcining them amidst the coals in a reverberatory furnace. So prepared they shine like glowing embers. He obtained phosphori from all earths which contained the sulphuric acid; and the earth of alum was the best, and some calcareous ones scarcely inferior. Some time after this, Mr. Canton of London produced a shining preparation of the same kind, by calcining oyster shells half an hour, and then reducing them to powder, and mixing them with one-third of sulphur. The mixture was rammed into a small crucible, and calcined for an hour in a clear fire. The mass, when broken, was found unequally luminous. The best parts were therefore selected, and were very brilliant. It is to be remarked, that different parts emitted light differing considerably in colour. Figures may be drawn on paper with white of egg, which will take hold of the powder and exhibit the figure in the dark. Canton's phosphorus equals any of the natural stones in brightness, and in the quickness in which it is saturated with light, so as to attain its greatest possible brilliancy. Indeed, in this respect, it may be thought superior; for Mr. Margraaf says, that two or three minutes exposure is necessary for his preparations. When this light emitted by these phosphori has expended itself, or is no more sensible, heating the body renews it for a little time; and when this has ceased, a greater heat causes another emission. But, in all these cases, a greater heat sooner exhausts the power of shining. In short, in this experi-

ment, heat operates in the same way as in expelling dampness, or any other volatile matter. Also a great heat applied to the phosphorus, while it is exposed to the light, hinders it from acquiring the luminous faculty. All these circumstances concur in strengthening the opinion, that this composition imbibes, and then emits something material, which is light, or the cause of light. Beccaria said that the Bolognan phosphorus most certainly did so, because, when illuminated by coloured lights, it emitted only the colour which had illuminated it. This would indeed be almost a demonstration of the doctrine of imbibition, and of the materiality of light; but the experiments of Mr. Wilson with Canton's phosphorus, render this doubtful. Certain parts emitted a particular colour, whatever had been the colour of the illuminating light.

When we reflect on the composition of this curious substance, we cannot but ascribe its shining to the same cause which produces the inflammation of the pyrophorus of Homberg. They consist of the same ingredients, united by the same process, and they continue to emit the same hepatic odour, though long kept, if kept from damp air. Accordingly, Mr. Macquer considers the shining of these phosphori as instances of a low and imperfect combustion, similar to what we observe in the phosphorus of urine, which begins to shine when exposed to the air, and by this shining, is slowly converted into phosphoric acid, still mixed however with a very great proportion of unburnt phosphorus in a volatile state. It is well known too, that sulphur, fat oils, suet, and many other substances, nay, even gunpowder when heated to a degree far below ignition, emit a faint lambent flame and suffocating fumes, which slowly consume them to a certain degree, and that this happens, without their becoming of themselves sources of heat sufficient for the continuation even of this low degree of inflammation. If an iron bar be heated red hot at one end, and allowed to become very hot also at the other end, and if we then make a line along it with a bit of tallow, or white bees wax, or sulphur, or rather make a set of detached spots, we shall see them shine with various brightness according to their distance from the hottest part of the bar, and the brightest are soonest exhausted of this faculty.

Macquer, therefore, ascribed these and all other phosphorescences to the same cause, and supposed that they were cases of slow and imperfect combustion. This opinion is very plausible, and is well supported by the emission of the hepatic smell, and some other appearances. Many kinds of spar are very luminous when thus heated. The Derbyshire fluor is remarkably so. Corrosive sublimate shines the brightest of all. Next to this is pure chalk, crude magnesia, earth of alum, vitriolated tartar, French chalk, &c. Mr. Wilson of London observed similar appearances in many other bodies,....indeed in most bodies of a white colour. Even paper had this property.

But there are circumstances attending the phosphorescence at present under consideration, which will by no means agree with this explanation. All the emissions of light just now spoken of require the application of heat, and the contact of vital air, and consume this air in the same manner as common combustion does. But the Bolognan stone, and the phosphori, of this class, require nothing but exposition to the light, and do not require the renewal of the air. Mr. Canton put some of his phosphorus into small glass balls, and sealed them hermetically, and found them as good as ever after twelve months subjection to every trial. He found this to be the best way of keeping his powdered phosphorus. After twelve months, two seconds exposition to the sun made it shine, so as to make the figures on his watch dial perfectly visible. An electrical flash, or even the light of a single candle, sufficed for causing it to shine. Long exposure to dry air impairs it, and damp air does this immediately. In short, these phosphori only emit the light they have received, or they are rendered luminous by the action of light alone. The first appears the most probable, because a greater heat occasions a brighter light and a more rapid exhaustion of all that will be dissipated by that heat. This is very like the expulsion of something received. Another circumstance confirms this. No length of keeping in the dark will hinder the emission of the light which had been imbibed, and would have been expelled by that heat. A ball kept fifteen months in the dark, after having been illuminated by the moon only, and which did not shine immediately after, on account of the weak-

ness of the light, was distinctly seen by plunging it into boiling hot water.

Mr. Canton found that humidity inclosed with the phosphorus, that it might stick to the glass, impaired it much, and destroyed it. Alcohol did not hurt it so much, and æther not at all. Æther, therefore, with a minute portion of resin or gum, would make the powder adhere as Mr. Canton wished. The phosphorus might be attached in this way to a plate of glass, and another plate laid on it, and the edges secured with varnish and paper pasted round.

These circumstances evidently distinguish this phenomenon from ordinary combustion. But it were worth while to examine by some proper train of experiments, whether the shining is effected by the absorption of vital air, and a subsequent decomposition by the action of fresh light. As humidity spoils the phosphorus, perhaps a permanent compound is now formed which fresh light cannot decompose again. We might perhaps learn this by examining the change produced after a long time on the air which was shut up with the phosphorus in a damp state. It would be proper to try this with two balls, one of them to be exposed day and night, and the other kept in the dark.

Mr. Wilson thinks that this phenomenon is not merely an imbibition and subsequent emission of light, but rather that light acts on some matter in the body, in such a way as to cause it to emit light. Thus only, he thinks, can we account for white light being emitted by a part which was illuminated only by a red or blue light.

The foregoing observations on the phosphori, properly so called, are, in my opinion, as interesting to the chemist as to the optician, and they are very interesting to both. To us, they are important, being nearly connected with the whole doctrine of combustion,....a doctrine still full of difficulties, notwithstanding the very great discoveries which have been made. The separability of light and heat by a plate of glass, in the valuable observation of Scheele, and their seeming separability in the present instances, are undoubtedly facts of great moment in philosophical chemistry, especially when considered along with

Herschel's observations. The observation also of Mr. Goettling, that phosphorus shines bright in azote and in volatile alkali, and the shining of vegetable and animal substances, (particularly sea fish) in a certain stage of putrescence, and their shining in *vacuo* and other situations incompatible with combustion, merit a much more careful attention than has yet been given.

The four inflammable bodies which have now been considered appear to us in the character of simple substances. I do not mean that they are elements, but only that we are not authorised, by any observation or experiment, to say that they are compounded of other more simple substances known to us in a separate state. We have never decomposed them, nor formed them by the union of known substances. We have only been able to extricate them from more complex bodies, and to shew that they are ingredients in their composition.

This simplicity, and the manifold relations of hydrogen, phosphorus, sulphur, and charcoal, have been of great service to us, by giving us a conception of the remarkable phenomenon of combustion, which is incomparably more agreeable to our general knowledge of chemical facts than the ingenious doctrine of Dr. Stahl, and is really supported by proofs which seem incontrovertible. Even though imperfect, this new doctrine furnishes us with a fact, formerly unnoticed, which accompanies all combustion, namely, the combination of the body called combustible with vital air. We shall find that this fact, when traced through all other cases of inflammation, will give us almost all the knowledge of chemical changes that we possess, and enable us to explain a vast number of the most complicated operations of nature, inasmuch as all explanation of phenomena consists in shewing that they are particular cases of general laws or facts already known.

We proceed now to consider inflammable substances of a more complex nature. In doing this, I shall still endeavour to introduce them to your acquaintance in the order of their simplicity, as far as I can perceive any gradation or order in this respect. With these views, I begin with *spirit of wine*.

V.....ARDENT SPIRITS.

VINOUS SPIRIT is produced from some vegetable substances by fermentation, and subsequent distillation. And the vegetable materials which by these processes yield the most of it are.

1st. The sweet juices of vegetables, in their naturally diluted state.

2d, The sugar, or sweet matter extracted from vegetables, when properly diluted with water.

3d, Grain, or other farinaceous parts of vegetables, malted and diluted in water.

4th, Grain, or other farinacea, dissolved or diluted in water, without being malted.

All these are capable of the vinous fermentation, by which the vinous spirit is formed; but not all with equal facility and perfection. They ferment the more easily and perfectly, and yield the more spirit, nearly in the order in which we have now enumerated them.

The nature of fermentation shall be considered when we treat of the vegetable substances in general. It is sufficient at present to know that the vegetable matter which undergoes fermentation, or a part of that matter, is changed by it into vinous spirit.

This spirit is at first diluted and combined in the fermented liquor with a large quantity of water, a portion of vegetable acid, some mucilaginous and colouring matter, and a small quantity of a subtile and volatile oil.

The spirit is separated more or less perfectly from these substances by distillation, it being more volatile than most of them, especially the acid, mucilaginous and colouring matter. The water is but imperfectly separated at first, on account of the small difference of volatility between it and the spirit.

To reduce the spirit to a state of purity, we must perform several other operations; such as distilling it again once or twice, with a gentle heat, which is called *rectifying*. By this we separate the greater part of the water which had come over in the first distillation.

But, even after these rectifications, it still retains a considerable portion of water, and along with it another ingredient which, being very volatile, always arises with the spirit, though distilled ever so often. This is the volatile oil, which I mentioned as being intimately blended with the spirit at first. The quantity of it and the flavour are different, according to the nature of the particular vinous liquor which we have chosen, and also according to the manner in which the fermentation has been conducted. It is this oily ingredient in vinous spirits which produces a diversity among them in point of flavour. When it is separated from them as much as possible, they are all alike, or are distinguished with difficulty. It is this oil which makes the spirit obtained from all sorts of grain in particular so nauseous at first, when compared with some others. This becomes most obvious in them when they are hastily diluted with water, being then more perceptible by its disagreeable smell and flavour, and often by some degree of milkiness, which appears when the spirit and water are mixing together, and for some time after.

In order to free the spirit from this oily principle, and from a portion of the water which it retains too strongly to admit of its being separated by distillation alone, we must have recourse to an elective attraction. And the usual method is to employ the common vegetable fixed alkali in its ordinary state, or in the state of pearl ashes. About one pound weight is added to every gallon of the spirit, and allowed to remain with it 24 hours. It is dissolved by the watery part of the fluid, and forms a liquor which remains at the bottom, and cannot be mixed with the spirit above it. The spirit may therefore be poured off from it into another vessel, in which we may add to it half a pound more of the same fixed alkali perfectly dry. This may not perhaps become perfectly liquid; but it may attract as much humidity as will make it soft, and will half dissolve it. After waiting 24 hours more, the spirit may be poured from this also into a clean vessel, and we may make a third addition to it of the dry salt. By these repeated operations, we bring it to that state of strength in which it no longer imparts any watery humidity to the dry alkali.

Thus we at last separate the whole of the water which the alkali can attract from it. But, at the same time, the spirit receives a disagreeable taste, and a yellowish colour. This happens in consequence of its dissolving a small portion of the alkali, which, acting on the volatile oily matter, produces the yellow colour. The quantity of alkali thus dissolved, is, however, but small, though it is sufficient to give the bad taste and flavour. But in order to separate this also, as well as the oily matter with which it is combined, another operation must be performed; which is, to distil the spirit with a gentle heat, until a small quantity of it only remains in the still. The alkali and oily matter will be found remaining with this small quantity in the still: and the spirit that has passed over in the distillation will thus be brought to the highest degree of purity and perfection to which it can be reduced by these operations.

The artists named rectifiers and compounders, who employ themselves in purifying coarse spirits, and changing their flavour, use also, in some of their distillations, a small quantity of the sulphuric acid, and sometimes the nitric. These act on the small portion of water, and of the oil which may still remain; and they diminish the volatility of both these ingredients: and by their action on the spirit itself, they communicate more or less of an agreeable flavour.

When spirit of wine is thus highly purified, it is lighter than water, in the proportion of 82, 83, or 84, to 100: and in this state it is called ALCOHOL. But I have sometimes brought it up to an higher degree of strength; so that, in the heat of 60° of Fahrenheit, 80 parts of it by weight were exactly equal in measure to 100 by weight of water. It was brought to this strength by distilling it with the addition of dry muriat of lime, which has a very strong attraction for water, and retains it powerfully in the distilling vessel. This intermédium for rectifying spirits has also the great advantage of not acting sensibly on the vinous spirit; and therefore imparts nothing of that disagreeable soapy taste and flavour which are often produced by the fixed alkalis.

Vinous spirits make an article of commerce that is very extensive. As they derive all their value from the alcohol which they contain, a method for accurately determining how much al-

cohol, and how much water, there is in any spirit, is a very valuable acquisition. This is best discovered by the specific gravity. A cubic foot of water, of the temperature 55°, weighs 1000 ounces precisely. The like measure of the purest alcohol that I have been able to prepare, weighs 800; and ardent spirits approach to this levity, in proportion as they contain alcohol. A mixture of equal measures of water, and of an alcohol which weighs 820 ounces, forms what is called **PROOF SPIRITS**. Its specific gravity is 0,925: or the weight of a cubic foot is nearly 925 ounces*.

When a vinous spirit is by such operations brought to an high degree of purity, it is an exceedingly fluid, penetrating, fragrant, and highly inflammable liquor, named by the chemists **ALCOHOL**; a word introduced into chemical language by the Arabians, and which means, I believe, something very subtle and elaborately prepared.

It is an inflammable substance, distinguished from the rest by its singular qualities.

In the first place, it has an extraordinary disposition to retain the form of fluid. The most intense cold that has yet been observed in nature, or produced by art, is not sufficient to congeal it.

Another remarkable property of alcohol is, a disposition to be much expanded by heat and contracted by cold. It is therefore often used in the construction of thermometers.

But thermometers made of it can only be employed in measuring intense colds, and the heats of the atmosphere and of animal bodies. In a heat equal to 174° of Fahrenheit, which is far below the boiling point of water, alcohol begins to be changed into elastic vapour, which, if allowed to increase in quantity, would burst the thermometer. Its expansion is not in proportion to its increase of temperature.

* There is considerable uncertainty in this. *Proof spirits* is that strength by which the liquor pays the excise duty. The statute by which this is imposed, declares that an English wine gallon, which is 231 cubic inches, or $\frac{231}{1728}$ of a cubic foot, shall weigh seven pounds and 12 ounces, avoirdupois weight. This gives $927\frac{6}{10}$ ounces for the weight of a cubic foot. The hydrometers used by the officers suppose it still weaker. (See *Encycl. Britannica*, **SPIRITS**.)

We may therefore reckon as a third of the remarkable qualities of alcohol, its volatility. In the vacuum of an air-pump it would boil and produce elastic vapour in lower heats than the ordinary heats of the atmosphere. And in an open vessel, even under the pressure of the atmosphere, it evaporates spontaneously much faster than water. If a person dip one finger into alcohol, and another into water of the same temperature, and then expose them to a dry air, the finger which was dipped into the spirit will immediately feel vastly colder than the other, owing to the more quick evaporation, and the rapid absorption of heat. Its latent heat is scarcely inferior to that of water, if it does not exceed it.

A fourth well known quality of it is an high degree of inflammability. The vapour of it, in whatever manner produced, is eminently inflammable. Whenever it is touched or approached by flame it immediately takes fire, and burns with a blue transparent flame, which has not the smallest appearance of smoke; and the whole of the alcohol is gradually consumed in this manner, with as little appearance of its leaving any earthy or other fixed incombustible matter behind. This, as I formerly observed, induced Dr. Boerhaave to consider alcohol as the pure pabulum of fire, or as a matter which was totally spent and consumed in producing heat and light. And he insinuates a suspicion that the other inflammable bodies may have their inflammability from alcohol present in their composition.

But this notion of its being totally spent and consumed by inflammation, and converted into heat and light, was a great mistake. The fact is, that it is converted into a great quantity of water.

Newman observes, that if we burn the purest alcohol in a deep vessel, such as a large brass mortar, and keep the sides of it cool by surrounding it with cold water, a quantity of water will remain equal to one-third of the spirit; and if we suspend another mortar inverted over the first, a quantity will remain equal to one-half; and that by other contrivances, which still more effectually condensed the watery vapour, he could obtain a much greater quantity.

I have long been of opinion that a quantity of water might be collected from burning alcohol equal in weight to the al-

cohol itself, or even exceeding it. And this has been found to be fact by some experiments ingeniously contrived and carefully executed by Mr. Lavoisier, in which he employed very effectual means for condensing the watery vapour which arises from its flame. He caused it to burn very slowly, under a tall chimney of thin plate surrounded by cold water. By a medium of repeated trials, he obtained nine ounces of water from eight ounces of alcohol burnt in dry air, yet the air unavoidably carried off with it a very sensible portion of moisture. (*See his Essays*).

Some part of this water was undoubtedly present in the alcohol before it was inflamed; for it is extremely difficult, and perhaps impracticable, to separate from it completely the whole of the water in which it is originally diluted. But as we get more of the water than there was of the alcohol, it is evident that the whole of this water could not be contained in it. Mr. Lavoisier, therefore, has accounted for the origin of it in another way, by supposing that alcohol contains a great quantity of hydrogen in its composition, and that the atmospheric oxygen combines with this by inflammation, and thus produces water. This supposition is founded on very satisfactory experiments, the first of which were made by Dr. Priestley, who published an account of them without attempting to build any theory upon them. And Mr. Lavoisier immediately afterwards repeated them with the greatest accuracy.

They were made by forcing the vapour of alcohol to pass through a red hot tube of metal or earthen ware. The greatest part of the alcohol was thus changed into hydrogen gas, or inflammable air, the bulk of which, on account of the rarity of that sort of gas, was astonishingly great, when compared with the bulk of the alcohol: for in the alcohol, it is not in the form of hydrogen gas, which is a compound of hydrogen and latent heat. It is in the dense form of hydrogen, destitute of that latent heat; and this, together with a small portion of carbon, makes up almost the whole of the alcohol; for it appears to contain, besides these two, a very small quantity only of some other principles; such as a very little oxygen and perhaps of azote. The presence of the carbon is known by a small quantity of very light charcoal which it

leaves in the red hot tube, and a part of which is dissolved in the hydrogen gas. And the presence of the oxygen is proved by a small quantity of carbonic acid gas, which is found mixed with the inflammable air.

Mr. Lavoisier, therefore, is of opinion that the greater part of the water which arises in vapour from burning alcohol is formed by the union of the hydrogen with the oxygen of the atmosphere, which contributes to its inflammation. This opinion appears to be very well founded.

Besides these ultimate principles which have been found in the composition of alcohol, we can extract from it, by some less destructive processes, a small quantity of vegetable acid, similar to vinegar or the acetous acid: and we can even convert a great part of it into that acid, by diluting it largely with water, and making it undergo a particular fermentation, to be described hereafter. But this is not surprising; as the acetous acid itself is now known to be composed of oxygen, combined in a particular and loose manner with carbon, and with a small portion of hydrogen. The small quantity of acetous acid, which is often concealed in alcohol, is lost however when the alcohol is consumed by inflammation. In passing through the outside of the flame where the heat is produced, it is burnt and destroyed, together with the carbon, and is changed by the oxygen of the atmospheric air into carbonic acid gas, and a small quantity of water. (*See Note 46. at the end of the Volume.*)

This may suffice for a general account of the nature of alcohol, and of the manner in which it is affected by heat. We must next consider its properties in mixture with other bodies....

One of these properties, which appears remarkable when we consider this fluid as an inflammable body, is its mixing so readily and completely with water in any proportion, which no other inflammable substance will do. It even shews a considerable attraction for water. When I have prepared alcohol of an extraordinary strength, I found it was difficult to preserve it in that state. It attracted humidity even through the corks of the bottles. This shews a very strong attraction between this fluid and water. And this attraction further appears by the readiness with which these two fluids

will deposit other substances that they may unite together. Most of the compound salts may be precipitated more or less from water by the admixture of alcohol. And alcohol, which can dissolve a variety of oils and resinous substances not soluble in water, deserts or deposits these, to unite with water.

The union of alcohol with water, in equal weights, produces eight or ten degrees increase of temperature: and the bulk of the mixture is less than that of the ingredients by one part in thirty-four.

It is this attraction which renders it so difficult to make alcohol very strong by distillation alone, although the alcohol in its separate state is much more volatile than water.

Among the saline substances, there are a number that act one way or other upon alcohol. We have already noticed one property of the common vegetable fixed alkali with respect to this fluid, that of attracting the water from it when weak, and therefore assisting us to make it strong. And I observed, that if much alkali be employed in this way, a small part is dissolved, and gives the alcohol a yellow colour and disagreeable taste, which can only be removed by distilling it slowly, until a small quantity only remains in the still. I must now add, that alcohol, thus tinctured with fixed alkali, has been esteemed a more powerful solvent of some subjects than a purer alcohol would be. And hence the chemists some time ago took much pains to learn the best manner of preparing it, or the way to have it as strong of the alkali as possible: and they called it *tartarized spirit of wine*. You will find that Dr. Boerhaave gave much attention to the combination of spirit of wine with alkali; and considered the preparing of a good tartarized spirit of wine as a nice and difficult operation. He recommends or enjoins attention to two particulars: 1st, To use the strongest or purest alcohol: 2dly, To use alkali of tartar well calcined, and put into the alcohol perfectly dry and hot. If there be the least moisture in the salt, or water in the alcohol, it will be impossible to dissolve the proper quantity of alkali. But I must add, that Dr. Boerhaave met with so much difficulty, in consequence of his using the alkali combined with carbonic acid, or in its ordinary state, as we find it in pearl-ashes or alkali of tartar;

that state of alkaline salts being supposed at that time to be their purest state, which it is not in reality, the caustic state of alkalis being the purest. If we take an alkali that is perfectly caustic, or totally deprived of its carbonic acid, we can dissolve as much of it as we please in spirit of wine, weak or strong, or though the alkali itself be not very dry; This property I discovered in the caustic alkali; and it is a consequence of its being more soluble, and its having a greater attraction for other bodies than mild alkali has. It unites with alcohol, as we have seen it unite with other inflammable substances.

Thus we have an easy method for making a tartarized spirit of wine, as it was called, as strong of the alkali as we please, which Dr. Boerhaave thought to be such a difficult business.

As the effects produced with alcohol by a fixed alkali, perfectly pure, are different from those produced by the same alkali in its ordinary state, so, on the other hand, are they very different, if we take the same alkali perfectly saturated with carbonic acid. If alcohol be suddenly poured upon a spirit of sal ammoniac, formed by dissolving as much as possible of the crystallized volatile alkali in water, the alcohol separates the salt from the water, forming a thick, and sometimes firm coagulum, called the *offa Helmontii alba*. It is a crystalline sponge, containing ardent spirits.

We shall now turn our attention to the mixing of this fluid with the different acids, taking them in their usual order: the sulphuric therefore in the first place....

This acid is known to act powerfully on the inflammable bodies in general; and it accordingly unites with alcohol rapidly and violently. It will be proper to pour in the acid at one side of the retort, by little at a time, that it may slide down under the alcohol; and after each addition, to agitate the mixture with a circular motion. Thus we temper the very great heat produced by the mixture. Equal weights may be thus mixed by cautious agitation with interruptions; but in whatever way we proceed, a violent commotion is excited, and a heat which the hand could not bear. A thin glass must therefore be used; for if we were to proceed so

slowly that the heat should never be considerable, we should lose much of the valuable product of the operation. Each of the first additions of spirits produces a puff of ebullition: but this becomes moderate by the time that two-thirds of the spirit have been mixed; and the mixture now requires somewhat greater heat to make it boil.

This mixture has not a little engaged the attention of the chemists, on account of some remarkable productions which are obtained from it when it is distilled. A condensing apparatus must be fitted to the retort: and this must be immediately set upon hot sand for distillation. This may be carried on at first with a pretty brisk heat. But this must be quickly diminished, when a certain sign (to be mentioned presently) appears, or when the liquor in the receiver is reduced to nearly one-half of the alcohol.

The distillation produces as follows:

1mo, There is condensed a clear liquor, of a penetrating diffusive aromatic odour, the quantity of which is equal to half the spirit of wine employed.

2do, Sulphurous acid and *oleum vini dulce* then come over. But to have these without danger, the heat must be gentle, and long continued: if otherwise, the matter boils over, and the hot froth cracks the top of the retort.

3tio, A thick bituminous matter or coal is left in the retort.

But the fragrant fluid which comes first, called ÆTHER, is the desirable product of this distillation, and the one on account of which it is commonly performed. It owes its fragrancy to a subtile and volatile oily fluid, which makes up the greater part of it, and which was formerly called the *vitriolic æther*, but now the *sulphuric*. As it is the principal product of the operation, I shall point out the best method of managing the process to obtain it in quantity, and perfect.

First, of the different proportions in which the acid and alcohol may be mixed together. The proportion of equal weights is the best for producing the greatest yield of æther from the same quantity of the materials. If more alcohol be taken, a great part of it rises unchanged. If a larger

proportion of acid is used, the mixture soon becomes black and thick, and forms sulphurous acid.

The chemists are indebted to Mr. Beaumè for having investigated the best manner of conducting this operation. He tried many different proportions ; and found that the one we have taken was the best. You may see an account of his experiments in his little volume on æthers.

In the conduct of the distillation, it was formerly the practice to apply a gentle heat, and distil slowly from the beginning to the end. It is, however, quite unnecessary to be so cautious at first; we may distil briskly in the beginning, and until the æther has distilled over. But then, indeed, it is absolutely necessary to diminish the heat greatly ; and the best way to do this is by removing the retort from the hot sand, and thus putting a sudden stop to the distillation. If we neglect to do this, the sulphurous acid begins to be produced so suddenly and abundantly, that it makes the matter in the retort boil over in the form of a black foam ; blows up the vessels ; and poisons the whole air of the house with an insupportable and suffocating stench.

The signs by which we may know when it is time to stop, that we may avoid this accident, are these....

It is time to stop when a quantity has distilled equal to one-half of the alcohol, or a little more. This critical period of the operation may be also perceived by the appearance of a whitish vapour, like a mist, appearing in the retort. And the bubbles formed in the retort by the boiling of the liquor are more numerous, and remain longer before they burst. The odour of the vapours perceived at the luting is also less fragrant than at the beginning.

Another reason for stopping is, that after having performed one distillation, we may perform a second with the same acid, by adding to the retort a quantity of fresh alcohol, equal in measure to the fluid that was distilled off, and then, proceeding as before, we obtain a second product, which is exactly similar to that of the first distillation. And in the same manner, by another fresh dose of alcohol, and a third distillation, we obtain a third product as good as the two first ; and this repeatedly a number of times. But after a certain number, suppose six or eight, the acid becomes too

weak, and has much less effect on the alcohol. In practising these distillations, a little of the acid always passes over along with the last of the æther, and is intimately blended with it: and as a small quantity of spirit of wine comes over in the beginning unchanged, it is always necessary to rectify the æther, or re-distil it, to have it quite pure.

This second distillation is very simple, requiring only a very gentle heat, the vessels to be well luted, and the operation performed with day-light. A small quantity of caustic ley is put into the liquor in the retort, to absorb the volatilized acid: and we must stop when two-thirds have come over, reserving the rest, which still contains æther, to be mixed with the materials for another process. Some prefer the cucurbit for this operation: but the retort answers perfectly well. (*See Note 47. at the end of the Volume.*)

It is time now to examine this æther, and attend to the properties of it which have attracted notice.

First, it is called an oily liquor, being a liquor which does not mix with water, except in small proportion. It was once represented as not mixable at all with water: but Mons. Lauragais has shewn that this was a mistake; and that water will dissolve one-tenth part of its bulk of æther, but no more. I knew this, and had been long in the use of mixing it with water, to give as a medicine.

Along with this oily nature, it is the lightest of all fluids, and of great volatility. Its specific gravity is about 0,735. A little of it poured out very quickly, evaporates, and spreads its flavour generally through the whole house in which the bottle is opened. A few drops from the height of the arm will seldom reach the floor. As it evaporates very fast in the spontaneous way, so also it very soon arrives at a boiling heat. It boils at about 100° of Fahrenheit, even under the pressure of the air. And when we examine its proper boiling point, by removing the pressure of the air, we find it as much lower than those of other fluids in the same circumstances, and far below the freezing point of water. (*See Note 48. at the end of the Volume.*)

Cold is produced also by the spontaneous evaporation of æther. Beaumè made Reaumur's thermometer descend below frost with cloths wet with æther, and wrapped round the phial.

Another quality for which æther is eminent, is inflammability. It is very liable to catch fire by the mere approach of a candle while we pour it from one vessel into another.... Therefore, as it cannot always be fully condensed, the operation for æther ought always to be performed in day light.

It is an usual experiment by itinerant showmen to throw a lump of sugar, soaked in æther, into a glass of warm water. When a candle is applied to the surface of the water, it catches fire, and burns in a very amusing fluttering manner. The heat of the water expels the æther in a stream of bubbles, which take fire at the top of the water. The glass must be deep and narrow, that the succession of bubbles may escape near enough to set each other on fire.

Æther burns with a remarkably bright flame, frequently emitting sparks more brilliant than the rest, and produces a sensible soot.

The remaining properties of this fluid are chiefly those of a solvent of many substances. It dissolves a number of resins, gums, &c. as we shall learn afterwards more particularly.

The medical qualities of this singular substance are also eminent, and deserve our notice. Internally taken in water, in the quantity of 10, 20, 30, or 40 drops, it is a powerful antispasmodic. But its effects as an external application are the most remarkable. Applied to the forehead in the palm of the hand, it performs all the wonders of Dr. Ward's volatile essence, in resolving spasms and removing nervous pains in a moment, as it were by charm. Toothache and headache commonly yield to it. I am inclined to think that it acts in such cases by a sort of revulsion. It brings on, in a moment, heat and inflammation upon the skin, which, to some, become insupportable. But it goes off immediately when the hand is removed. It brings on this superficial inflammation more quickly than any blister, sinapism, or such application; and it is much more under command; for as soon as the hand is removed from the part, the heat and uneasiness abate, and soon go off entirely. I am therefore persuaded that it is very proper in many cases in which it has not been thought of, as in pleuritic stitches, rheumatic pains, and other such cases, in which blistering and cupping are of

service. There are many such cases, in which it is expedient to apply remedies of quick operation. Rectified æther should be used.

Of the effects of mixing alcohol with the nitric acid, chemistry furnishes many examples, which are remarkable, both for the appearances which they exhibit, and the information that we derive from them.

This acid, when obtained from nitre by the process formerly described, and which has the name of *Glauber's smoking spirit of nitre*, and was thought the strongest and purest, is in fact the weakest as an acid, and impure. It is a mixture of two acids, now distinguished by the name of NITRIC and NITROUS. The Latin names express their distinction more precisely, *nitrosum* denoting an abundance of that which distinguishes it as nitrous, viz. the fiery colour, the copious deep blood-coloured fumes, and offensive suffocating smell. The *nitric*, on the other hand, is colourless, and emits no sensible fumes. Yet, in all the distinguishing properties of an acid, it exceeds the other, having a much stronger attraction for water, alkali, and every thing that is dissolved by it; nay, even for that which seemed to characterise the excellency of the other,...I mean for inflammable substances. It acts on all substances much more violently than the nitrous; dissolves more alkali, earth, or metal, or even inflammable substance; and its virtues are permanent: whereas the red fumes of the nitrous acid waste by exposure, and the acid becomes unable to dissolve the same quantity of alkali as before. It was long suspected, therefore, that Glauber's spirit of nitre was a compound; and that it contained inflammable matter combined with it, arising from impurities in the nitre employed in the process for obtaining it. This suspicion was confirmed by observing that small additions of the more inflammable substances to the colourless acid immediately produced that fiery colour, and those red fumes, for which Glauber's spirit of nitre is remarkable.

I was the first, I believe, who entertained a notion somewhat distinct on this subject. Finding that Glauber's spirit of nitre, when distilled to about two-thirds of its bulk, had lost entirely its fuming quality, and that the liquor which came over possessed it more eminently, while the first was

stronger as an acid, I was led to consider the original liquor as a mixture of two separable substances, of which that was the compound which exhibited the weakest action on the substances which are dissolved by both. This I conceived to be conformable to the general facts in chemistry.

I was therefore disposed to consider Glauber's spirit of nitre as a compound of the acid of nitre and inflammable matter, or perhaps of the principle of inflammability. With this view of the subject, I tried to form anew this fuming spirit of nitre, by adding to the pale spirit of nitre a small quantity of alcohol, which I considered as an inflammable substance sufficiently simple not to contaminate the new compound with unsuitable ingredients. And I succeeded quite to my wish. A very minute portion of alcohol being added to a quantity of the pale and very strong acid of nitre, from which I had separated the highly fuming acid by distillation, immediately imparted to it the fiery colour and blood red fumes, and made it in all respects similar to Glauber's fuming spirit of nitre, having all its properties. This was, I think, in the year 1760.

This experiment being very instructive, it will not be amiss that I tell you the method of making it in the neatest and most perspicuous manner. Take a glass tube, about one-tenth of an inch in diameter, and draw one end of it more slender. Having put the acid into a solution glass, dip the small end of the tube five or six inches into spirit of wine; and then, closing the top of it with the finger, take up the spirit with it, and dip it to the bottom of the nitrous acid. Then, taking off the finger, let some (about half an inch) of the spirit run out of the pipe into the acid, and then stop the pipe again. You will see the union take place immediately, and small bubbles form on the mixture, few of which will reach the top. The whole will acquire an orange colour. Pursuing this method, you will see the progressive alteration very distinctly. One of my students, at Glasgow, asked me, after lecture, whether inflammable air would answer the same purpose, seeing that some imagined it to be the principle of inflammability. The thought pleased me: and I tried it with perfect success. It produced the same effects; but required an immense quantity; which did not surprise me, by reason of its great rarity.

But this mixture of nitric acid and alcohol merits further attention. I found that, by gradually adding more alcohol, the volatility of the acid, or a disposition to emit red fumes, increased, and the attraction for water, and its acidity, diminished; and that, by proceeding in this manner, the acid may be totally dissipated in those offensive fumes, leaving only acidulated water, having no inflammability, nor the smell of nitrous acid, but rather that of vinegar, which it also resembles in taste and in its mixture with other substances.

This process is accompanied with great heats, notwithstanding the copious eruption of these fumes: and it is very hazardous, because every addition produces a great and sudden increase of heat, which contributes to increase the explosive power of the mixture, and will throw it about the room, while the vessels run the risk of splitting by the sudden changes of temperature. To succeed to the degree I have mentioned requires a very long time, mixing very small portions of alcohol at once, and keeping both ingredients in vessels surrounded with ice and water. It will often be observed, that, after alcohol, amounting to one-fourth of the weight of the acid, has been added, the explosions are colourless and transparent, and are accompanied with a fragrant smell, resembling that of vitriolic æther. This indicated the production of something different from the nauseous blood red fumes, and gave the chemists hopes of obtaining an ætherous fluid, different from the vitriolic.

They were better conducted to this by another mixture, well known in pharmacy,....the preparation for obtaining what is called **DULCIFIED SPIRIT OF NITRE**. This is prepared by cautiously mixing with rectified spirit of wine, one-fifth or one-fourth of its weight of strong nitric acid, and distilling the mixture. It produces a liquor with no remarkable acidity, having a fragrant smell, much resembling that of apples. This encouraged to extend the addition of acid to the alcohol. Their mutual action was incomparably more quiet and manageable. For, as it already appears that a very small quantity of alcohol gives this ungovernable volatility to a great deal of the acid, it is plain, that, since a small quantity of acid is not converted at once into incoercible steams by mixing with a great proportion of alcohol,

repeated additions of such small quantities, after the heat and ebullition produced by the preceding addition have ceased, must in all probability be quiet and safe. So the case turns out; but still, although the successive mixtures go on without much trouble, it is found that when something more than one third of acid (by weight) has been added, the mixture begins to explode and become troublesome; and, if one-half be added, it is almost unmanageable. Mr. Navier, a French physician, was the first, I believe, who published a practicable and successful process, founded, I presume, on similar observations. He prescribes the cautious and gradual mixture of one-half of acid with the alcohol, in a very strong glass vessel, which he immediately corks up, and secures the cork with leather, tied hard over it, and secured by packthread; and the bottle is kept in cold water. Thus are the elastic steams prevented from forming, by the great pressure, produced by those already generated. The fluids gradually act on each other; and an æther is produced, which, like the vitriolic, floats a-top. As all this goes on under a very great pressure, it is plain that if we pull out the cork, or even untie the packthread, the elastic explosion will take place in an instant, through the whole liquor, and it will be thrown out. Mr. Navier, therefore, directs the cork to be pierced with a pin, and the vapour allowed to escape. After this, the æther may be separated by a funnel. It amounts to one-third, or one-half of the alcohol.

This process was still hazardous; for the bottle often burst. Mr. Beaumé, of the French Academy of Sciences, improved this process, by carefully investigating the best proportion and manipulation. He found that two parts of acid to three of spirits gave the greatest produce of æther from the same alcohol, and directed both ingredients to be used in the coldest state, by keeping each in melting ice, or water and ice, and by setting the corked-up bottle in the same situation. This proportion of ingredients secures us against the chance of explosions wholly ungovernable: and the low temperature greatly moderates the action that is unavoidable. He also directs us to give the liquor in the bottle a brisk whirling motion immediately before pouring in any more acid. This prevents any accumulation in a particular spot.

By this process we obtain, in three or four hours, a considerable quantity of æther, which is observed to form in little drops all over the liquor, and rise gently to the top. But allowing the bottle to remain undisturbed for eight or ten days, we obtain about half the weight of the alcohol, after which no more is produced in these circumstances.

I am by no means certain that this process will give the greatest product. I suspect that the external pressure really prevents the chemical union, in the same manner as it certainly prevents it in the boiling of water. That it is prevented in this instance is evident, because heat is not absorbed unless the pressure be removed. Therefore the heat is not combined when vapour is not produced. The like may happen here. I am justified in this, from observing that more nitric æther is obtained by other artificial processes, in which this pressure does not take place. I shall mention one, which I practised before I heard of those of Navier and Beaumé, and which is extremely simple and easy.

Into a strong phial, having a ground stopper, I first pour four ounces of strong pale nitric acid. I then add three ounces of water, pouring it in so gently that it swims on the surface of the acid. I then pour in, after the same manner, six ounces of alcohol. I put in the stopper slightly : and I set the phial in a tub of water and ice. The acid mixes slowly with the water ; and, in a diluted state, comes in contact with the alcohol, on which it immediately acts, and æther is produced slowly and quietly. The liquor gets a dim appearance, because imperceptible bubbles are formed, which rise to the top : and having collected to a certain degree, they lift the stopper and escape. After eight or ten days, I find upwards of three ounces of nitric æther, though I am certain, by the smell, that much escapes with the vapour. This is, however, a certain, easy, and safe process, though it is slow and imperfect.

More artificial processes have been followed by several eminent chemists.

1. Mr. Woulfe's, in his general manner of managing all distillations where fumes of difficult condensations are produced. He uses a succession of receivers, which are tubulated. A tube

goes from the top of the first into the second, down to the bottom, and another from the top of the second into the third, and so on. By this contrivance, what is not condensed in the first receiver, is condensed in the liquor of the second, &c. A mixture of equal parts of strong acid and alcohol is thus distilled with a very moderate heat; and a good produce of æther is obtained.

2. Nitric or nitrous acid is made to act, in the very instant of its formation, on alcohol. Nitre is put into a tubulated retort, to which is fitted a receiver. Vitriolic acid is poured on this, and immediately after, spirits of wine. The nitrous acid is disengaged, which rises through the vitriolic; and acts on the alcohol: and æther is produced, whose steams are condensed in the receiver.

3. Instead of putting the alcohol upon the vitriolic acid and nitre, it is put into a glass vessel, which communicates, by means of a bent tube, with a large receiver luted to the retort, containing the nitre and vitriolic acid. Heat being applied to the retort, the nitrous acid is disengaged, and part of it is condensed in the receiver; and part passes on to the bottle containing the alcohol, on which the vapours act: and æther is produced without any troublesome explosions.

Mr. Chaptal, who prepares a great deal in the way of commerce, uses two receivers in succession, the first being set in water, and the second covered with wet cloths: and it has a tube proceeding from the top, which is bent downward, and immersed in a bottle of water. He says that the process is easy and sure, affording very pure æther, and in good quantity.

But all the processes, and indeed every treatment of nitric acid with alcohol, requires much caution, that we may escape accidents.

The residue of the distillation is acid, much changed in its properties, appearing more like vinegar, or even more resembling the acid of sorrel, or of sugar. It burns to a coal, and produces, by a great heat in close vessels, carbonic acid, and empyreumatic oils, like all other vegetable substances.

The æther of all the processes here described requires rectification, to clear it of acid and alcohol, which come over with

it in the distillations, or mix with it in the processes by digestion. This rectification is performed by distilling it from caustic alkali. This reduces its quantity ; for we must not distil more than two-thirds or one-half of the first æther. To bring this to still greater purity, some direct it to be mixed with one-fifth nitrous acid, and distilled again,...taking two-thirds of the product set apart, and rectified from caustic alkali. The rest of what comes over is a less perfect æther,...the *mineral anodyne liquor of Hoffmann* ; and the remainder in the retort is a *dulcified spirit of nitre*.

Pure nitrous æther greatly resembles the vitriolic in lightness, inflammability, and flavour. This last quality, indeed, is inferior to the vitriolic, being stronger, and somewhat pungent. The taste is also more acrid ; the colour inclines considerably to yellow. It burns with a brighter flame than the vitriolic, produces more smoke, and leaves a stain in the dish. When kept, it is apt from time to time to blow out the cork. This is attributed to æther not yet perfectly formed ; and is said never to happen, if the produce be carefully rectified from caustic alkali, and if we do not take too much of what comes over.

The muriatic acid, in its ordinary state, exhibits no disposition to act on alcohol, or any other inflammable substance. But the chemists, curious after a knowledge of this new discovered fluid, the æther, were eager to compose one by this acid also, although their then received theories gave them little encouragement to expect it. Many attempts, however, were made, but long without success.

The simple mixture and distillation of the muriatic acid and alcohol has no effect. The mixture is indeed called the *dulcified muriatic acid* ; but there seems no combination or change of properties. Nor has better success followed the attempts to combine them in the instant of the production of the acid, or by uniting their vapours. At last, methods were discovered, in which, by employing the acid in a compound and peculiar state, a combination took place, and muriatic æther was produced. Of some of those methods I shall give you a short account.

I. The Marquis de Courtanvaux mixed alcohol with a liquor

called *the smoking liquor of Libavius*. This as you will learn afterwards, consists of muriatic acid surcharged with oxygen, and united with tin. Alcohol, being mixed with twice its weight of this liquor in a retort, produced heat and white suffocating vapours, but accompanied with an agreeable smell. When distilled, we first obtain a stronger alcohol : and then the æther appears, indicated by the smell, and by trickling down the sides of the receiver. After some time, the smell becomes suffocating. The receiver must now be removed, otherwise the æther will be tainted with many products, such as acid, oil, a substance like butter, &c. which you will understand afterwards.

The æther thus obtained must be rectified from caustic alkali : and only half of what comes over must be taken.

II. Similar to this is the process of the Baron de Born. He uses a compound of muriatic acid and the flowers of zinc. (*Mem. des Savans Etrangers*, VI.) The acid obtained from twelve pounds of sea salt, being saturated with the flowers of zinc completely dissolved, the solution is evaporated till of the consistence of grease. This is mixed very gradually with six pounds of alcohol : and after digesting the mixture eight days, and filtrating it, the clear liquor is distilled beginning with a very gentle heat. We obtain,

1. Water, amounting to almost half of the spirits.
2. An aromatic spirit of wine. The matter in the retort now grows thick like melted wax.
3. Æther. When this has all passed, the matter in the retort is dry and the heat must be increased.
4. A sweet oil like essence of lemon. This will swim on the æther, and is the last volatile product.

Great care must be taken that the heat be not too great before the matter in the retort becomes dry : for it is apt to burst up in sudden clammy bubbles, which, touching the colder parts of the retort, will split it.

The æther must be rectified from the aromatic spirit, by the gentlest heat of a lamp furnace ; and the spirit which remains may be poured back on the residuum in the first retort, and more æther, &c. obtained, in the manner practised for vitriolic æther, without end.

The author obtained by this process two pounds of æther, and four ounces of the sweet oil, both of which were remarkably fragrant.

III. Mr. Woulfe made muriatic æther by causing the vapour of boiling alcohol to meet with the muriatic acid gas, as it was disengaged from sea salt, in a glass vessel, from which a syphon tube proceeded into another glass containing alcohol. The tube reached almost to the bottom of the alcohol: and the vapours which did not condense here escaped, and went by another glass tube into a second vessel containing alcohol: and what was not condensed there went into a third, and so on. By this management the union was effected, and æther obtained in each of those vessels, swimming on the alcohol. These portions were mixed and rectified by distillation with a gentle heat, from caustic alkali, being much contaminated with acid vapours. The whole process was extremely tedious and troublesome, requiring several cohobations, or returning the liquors back again upon the residuum, before a tolerable quantity of æther was obtained. The vessels of alcohol were heated to a great degree by condensing the vapours, and soon gave over condensing. (*See Phil. Trans.* 1767.)

IV. A Mr. Schroeter of Berlin prepared a muriatic æther by distilling from a mixture of eight parts of sea salt, four of sulphuric acid, four of black manganese, (a substance containing much oxygen) and three of alcohol. In this process, the muriatic acid was disengaged from the sea salt by the sulphuric, and, in its nascent state, acted on the alcohol, being assisted by the manganese (without which we know that it will not succeed) in such a way as to produce abundance of æther. Mr. Pelletier of Paris, by a similar process, obtained four ounces of æther from eight of alcohol. The manganese evidently appears to favour the production of æther exceedingly. If the ordinary muriatic acid be distilled from manganese, its properties are remarkably changed: and if employed in this state in Woulfe's manner, it produces æther with great facility. There is, therefore, something which it possesses, in this state, and in those of the muriats of tin and of zinc, that is similar, and which fits it for this preparation. This change on the muriatic acid will be minutely considered in due time.

The æther obtained by any of these processes, when pure, is like the other two, immiscible with water except in a small degree, extremely light, highly odorous and penetrating, but much more offensive to the lungs than they are. It is highly inflammable; and in burning has much smoke, and emits a smell as penetrating as sulphuric acid. It is less agreeable to the taste, having the styptic taste of alum.

Thus we see that the three principal acids have in one respect a similarity in their action upon vinous spirits. Even the muriatic, which, in its ordinary state, shews no action on inflammable substances in general, or on this one in particular, can be put into such a state, competent to it as an acid, which enables it to contract an union with alcohol, or produce a change on it, similar even to that produced by the nitric, which acts the most violently of all on them. This must be considered as a common property of the acids, which it behoves the chemical philosopher to investigate in his own way. A chemist is disposed to ascribe it to some ingredient common to the acids. And we are interested to discover what this may be.

This may be considered as giving a theory of æthers, or an explanation how they are produced. They were discovered at a time when chemical science had made considerable progress, and its cultivators were eager to give a rational account of the many surprising effects or changes which it presents to our view. Therefore attempts were soon made to explain all these appearances.

One of the first who attempted this was Mr. Macquer. He imagined that the production of these light oily fluids was nothing but an abstraction of water from the ardent spirits; and that this was effected by the strong attraction for water, which is a distinguishing property of all the acids. By this abstraction of water, he conceived the alcohol to be reduced to its state of purity. And this he thought was a compound of a subtile oily principle and water strongly combined, and which, by the presence and quantity of the water in its composition, becomes miscible with water in any proportion. The acids, by their strong attraction of water, rob the spirit of a part of its elementary constitution, rendering it more inflammable and oily, and no

longer so miscible with water, but more volatile and inflammable.

But this theory is insufficient for explaining the phenomena. It is incongruous with the general train of chemical facts, that depriving ardent spirit of water will diminish its attraction for it. And it is not fact that the acids which have the strongest attraction for water are the most effectual for changing alcohol into æther. Acetous acid, which has a weak attraction for water, produces more æther from a quantity of alcohol than the fossil acids do. And the muriatic acid, which attracts water with great force, produces æther with great difficulty, especially when employed in that state in which it attracts water most strongly. It should also be a consequence of Mr. Macquer's theory, that all æthers should be alike, which is very far from being the case.

Mr. Berthollet, a chemist of the first eminence, thinks that all the æthers are formed merely by the addition of more oxygen to the composition of the alcohol. This opinion seems chiefly founded on the necessity of employing acids, which abound in oxygen, and on the phenomena and consequences of some of those processes, which shew the acid to be very much deoxygenated.

But I confess that I view the formation of the æther in a different light. When the processes are conducted in the best manner, we have no appearance of deoxygenating the acid during the formation of the æther. The sulphurous acid does not appear till all the æther has passed over. And we obtain the greatest quantity of nitrous æther, when we succeed best in preventing the explosion and the deoxygenation of the acid. When we neglect the precautions for preventing this, such as the keeping the mixture very cold, and making the additions very gradually, we have red fumes, indicating the deoxygenation of the acid, and we obtain less æther.

I am persuaded that the æthers are compounds of the alcohol, with a greater or less portion of the acid employed. The acids which are most abundant in oxygen are the fittest, for this reason, that they have the strongest action on alcohol and other inflammable substances. I believe that the acid is combined

with the alcohol, so as to be neutralized by it, while the attraction of the alcohol for water is diminished, for the same reason, and in the same manner, as the attraction of both acids and alkalis for water and other substances is diminished when they are combined in forming a neutral salt. The alcohol, therefore, assumes that immiscible and oily nature which is observed in it. That an oily appearance and consistency may be produced and increased in this way, is evident from the example of the *oleum vitrioli dulce*, which has more the appearance of an oil than the æther itself. Yet it is only æther super-saturated with acid. The æther is totally convertible into this oil by repeated distillation with the acid; so is also the nitrous æther. The presence of an acid in the most perfect æthers has been proved by Crell and Scheele. Both of these chemists have substituted one acid for another in the same æther, so as to change one æther into another, in a certain order. Were pure oxygen all that is united with the alcohol in forming æther, all acids would be indifferent, and all æthers alike.*

Mr. Lavoisier has been the most successful in explaining many phenomena in the action of the acids on alcohol and similar substances, and has made many judicious, accurate, and instructive experiments with this view. His explanations are founded on a careful analysis of the ultimate constituent principles of alcohol, and of the vegetable substances from which it is produced.

Mr. Lavoisier's opinion was, that the vegetable substances in general, and those susceptible of fermentation, such as sugar, mucilage, farina, and the like, are composed of carbon, hydrogen, and some oxygen, loosely joined, and in various proportions. By receiving more of the oxygen from the nitric acid, when it acts on them, or from the air, in the acetous fermentation, they are changed into vinegar, or some other acid. When the nitric acid is made to act violently, it produces effervescence and elastic matter: 1. By the changes which the nitric acid undergoes into *acidum nitrosum*, or into nitrous air, according

* Do not the more brilliant flame, and the smoke and soot, indicate a redundancy in the carbon rather than in the oxygen?....EDITOR.

to the degree of deoxygenation; 2. By the change of part of the carbon into carbonic acid gas, in consequence of its close union with part of the oxygen of the nitric acid.

Alcohol is composed of the same principles which compose these vegetable fermentable substances. But the principles are combined in the alcohol in different proportions from those which constitute sugar, and the rest of them. In alcohol there is a less proportion of oxygen to the others, especially to the hydrogen. In consequence of this it is more inflammable and volatile than those other vegetable productions.

The carbonaceous matter in alcohol is clearly exhibited in the experiment of Priestley and Lavoisier formerly mentioned, where the vapour of alcohol was made to pass through a red hot tube. It also presents itself in the process for sulphuric æther, by imparting a black colour to the acid in the retort, in proportion as the æther forms, and oxygen is abstracted from part of the acid. Its place is supplied by the carbon expelled from the alcohol by this elective attraction. At last, the matter in the retort becomes coaly; and a considerable quantity of very fine charcoal is elevated. It is probably thus partly retained and separated from the other elements of the alcohol, by the strong attraction of the sulphuric acid, which, when the distillation is too long continued, is imperfectly decomposed by it, and changed into sulphurous acid: and the vapours of this volatile sulphurous acid, in conjunction with the carbonic acid gas, into which a part of the carbon is changed on this occasion, explain the violent and sudden ebullition of the matter in the retort, and bursting of the vessels, when the distillation is pushed far with too great a heat. And during the formation of nitrous æther, there is always a little effervescence or a production of gas, formed from a part of the carbon changed into carbonic acid by some of the oxygen of the nitric acid, which, being thus partly changed into azotic gas, contributes to make up the quantity of the elastic gas. And along with these gases, vapours of the nitrous æther, formed in consequence of its great volatility, also escape. The matter of these different gases, however, can be confined and made to remain combined with the nitrous æther for some time; of which we have an example in Mr. Navier's

and in Mr. Beaumé's processes for nitrous æther; the strong pressure to which the materials are subjected in the corked bottles repressing their volatility. But whenever the bottle is opened they are sure to escape.

All the æthers, therefore, as I said before, appear to be compounds of the alcohol, and of a small portion of the acids made use of. A part only, and that very little, of the acid is decomposed, less or more, by the loss of some oxygen during the process: and a part only of the carbon is taken from the alcohol. Æthers, therefore, contain a less proportion of this principle, and a larger one of the hydrogen than alcohol does. This idea appears probable, from the lightness and volatility of æther, and from the black colour and other appearances of the acid which remains in the retort in the distillation to obtain sulphuric æther.

The experiments you have now seen with mixtures of alcohol and nitric acid confirm the character of this acid, which is eminent by a disposition to act violently and powerfully on the inflammable substances, and others allied to them, which powerful action of it plainly depends on the great quantity of separable and active oxygen which it contains.

Of this we have another eminent example in the action of sugar and nitric acid on one another.

Some of the qualities of sugar are sufficiently known to you, such as its solubility in water, and the crystals called sugar-candy which it forms, when the solution of it, or syrup, is properly crystallized. Loaf sugar is only a mass of very small crystals cohering together, and therefore more readily soluble.

Sugar is entirely a vegetable production, and is found in the juices of many vegetables. It is commonly obtained from the juice of one plant, which abounds with it the most of any, viz. the sugar-cane. But many other vegetables, or parts of vegetables, contain some sugar. It is often crystallized or concreted in fruits that are dried.

As sugar is always a vegetable production, not being found in any other part of nature, we may expect to find in it the same elementary principles of which vegetables are composed, or some of those principles. Accordingly, when it is subjected to the most destructive kind of analysis by fire, it yields a large

quantity of hydrogen gas, mixed with carbonic acid, and holding dissolved a small portion of the carbon not combined with oxygen. But a considerable portion of carbon remains behind in the apparatus, in the form of charcoal. From the result of this analysis, it is plain that sugar is composed of carbon, combined with hydrogen and with some oxygen at the same time. These two last ingredients are in their dense unelastic state. And all the three are combined with that weak attraction with which the elements of vegetables are known to cohere.

You can easily imagine that such a compound as sugar may be made to receive a larger quantity of oxygen than that which it naturally contains. And this is found to be true, when we apply to it the nitric acid. But no one can imagine, till he has seen it, the violence with which the action goes on. When a bit of loaf sugar is put into nitric acid, it is some time (about three or four minutes) before the combination becomes observable. Small bubbles begin to detach themselves, and immediately on their reaching the surface, acquire a deep blood red colour. The liquor becomes warm: and the emission of bubbles becomes more and more copious, till the whole is in violent ebullition, and the upper part of the vessel is filled with the blood red vapour, which becomes transparent; and the production of those red vapours goes on till the sugar is dissolved or consumed, and the liquor acquires the greenish colour of fresh made aquafortis.

If this mixture be made by employing common aquafortis, a gentle heat is required: and then the phenomena are nearly the same in kind, though in a much more moderate degree. What I chiefly mean to consider just now is the vapours which are produced. They are found to consist of oxygen and azote, the same which I have given as the constituent parts of the nitrous acid. But they are in a very different proportion, being nearly as 68 to 32; and require a great addition of oxygen to make them equivalent to nitric acid, or even to nitrous acid. When pure, they are not only transparent, but as colourless as common air, and are perfectly incondensable by pure water, or ordinary cold. The deep red colour acquired by the fumes, arises entirely from the mixture with the vital air of the atmosphere. The gas

combines with oxygen, and the two collapse into nitrous acid. If a glass jar, filled with vital air or oxygen, be inverted on water, and some of the gas obtained from sugar, in the way now described, be let up into it through the water, we have an instantaneous deep red cloud, and the water rises to the top of the glass, in consequence of the collapsing of the two gases. It contracts no such union with azote or carbonic acid gas. From this account you see that it is the fluid called nitrous air, or nitrous gas (as the French call it) which was first discovered by Dr. Priestley, but produced by him by other processes than this. And by making a great number of experiments with it, he made many useful, interesting, and instructive discoveries. I shall shew the principal experiments with it soon,....when we shall have an opportunity for preparing it in a more perfect and pure state than this. I shall only remark on it at present, that it is the nitric acid changed to a much greater degree from its common state than it is in the *acidum nitrosum*, and this in consequence of having lost a greater proportion of its oxygenous principle. And therefore it has no perceptible acidity, and but little attraction for water. It retains, however, the disposition to unite again readily with oxygen: and in uniting with it, forms first the *acidum nitrosum*, and afterwards, with a larger quantity, the most perfect nitric acid.

These are the changes produced in the nitric acid while it and sugar act on one another.

The sugar too, as might be expected, undergoes a great change. It totally loses its sweetness; and is converted into a perfect acid by its union with the oxygen of the nitric acid.

Mr. Bergmann, by distilling aquafortis from one-sixth of its weight of sugar, obtained a prodigious quantity of the gas just now described, and reduced the sugar to a pure acid salt, called the *ACID OF SUGAR*. It crystallizes in four-sided spiculæ, terminated by a ridge.

The acid of sugar, exposed to a heat gradually increased to a red heat, first effloresces, losing its water of crystallization, and then becomes brown, and emits compounded vapours, which, by careful treatment, condense into the same products that are obtained from all vegetable substances, or remain

in the form of elastic gases ; that is, empyreumatic acid and oil, soot, and a great quantity of carbonic acid and inflammable air. Part of the salt, however, sublimes, no way differing from its original form.

When examined in the way of mixture with the substances which we have already considered, it exhibits several remarkable properties.

With the mineral alkali, it forms a salt of difficult solution, having an excess of alkali in its crystals.

With the vegetable alkali, it forms a deliquescent salt, when perfectly neutral, but which crystallizes when either ingredient exceeds in a certain proportion.

With volatile alkali, it forms a salt which crystallizes in four-sided prisms. This salt is decomposed in a very singular manner by heat, namely, by the destruction of its acid : and we obtain very mild volatile alkali, formed by the carbonic acid which arises from the destruction of the acid. It is worthy of particular remark, that no deflagration appears in treating the acid of sugar, or its compounds, by great heats, nor is any azote obtained. This shews that it does not owe its acidity to its containing nitrous acid, as was supposed when it was first discovered.

With lime, it forms a salt insoluble in water (if that name be competent to such a substance). It is very remarkable that the attraction of this acid for lime exceeds that of the three mineral acids. Lime also decomposes the three salts already mentioned. Acid of sugar, therefore, will detect lime in mineral waters, by taking it from every other solvent.

It forms a white powdery salt with magnesia, and with barytes ; which last earth decomposes the magnesian salt.

Acid of sugar dissolves in sulphuric acid, giving it a brown colour.

Nitric acid acts on it, and decomposes part of it : and we obtain, by distillation, vinegar and carbonic acid.

If fresh nitric acid be distilled from what remains, we have the same products.

When this action of nitric acid and sugar on one another was first discovered by Professor Bergmann, it was supposed that the acid we obtain was a principle or production peculiar

54 SACCHARINE ACID, OR ACID OF SORREL.

to sugar. It was therefore called the *acid of sugar*. But by similar experiments, which have since been made on a variety of vegetable and animal substances, subjected to the action of the nitric acid, we have learned that the acid acts on them all in a similar manner; that is to say, with similar effervescence and the production of similar elastic fluids; and that many of those substances are thus changed also, at least in part, into an acid exactly similar to that obtained from sugar, although they are not at all sweet, nor appear to contain any sugar. This happens with the vegetable mucilages and glues, gum arabic, tragacanth, and others; also with starch, and the mucilaginous part of lemon juice. Its presence in this last was discovered by Scheële: and he evinced its being the mucilaginous part of lemon juice which contained the saccharine acid, by crystallizing the acid of lemons, and then examining this for the saccharine acid. It contained none. *Note*, That the citric or lemon acid is very easily crystallizable, by first combining it with lime, and separating them by means of the sulphuric acid. Even alcohol yields a little of this acid, when the action of the nitric acid on it is violent and long continued. Many animal substances yield it also, as Mr. Berthollet discovered: and some of them yield it in much greater quantity than sugar does. Sugar yields one-third of its weight. Wool more than one-half.

There is, therefore, no good reason now for calling it the acid of sugar, especially since it has been found ready formed in some other vegetable substances, as in sorrel. Since this acid has been well examined and characterised, the salt of sorrel has been found to contain it, and to derive its acidity from it; the salt of sorrel itself being an alkali supersaturated with this acid. *Vide Bergmann on Elective Attractions.*

We may here further remark, that all the vegetable acids are more or less similar in their composition to the acid of sugar, being composed of hydrogen, carbon, and oxygen, in different proportions. All these salts are convertible into one another *in a certain order*, by the action of the nitric acid on them. The acid of tartar is changed into the oxalic or saccharine; the oxalic into the acetous; and this into the

carbonic. But this department of chemical analysis is yet in its infancy: and it will probably be a long while before any perspicuous knowledge of it will be acquired. We run a great risk of being led into important mistakes, by too confident application of imperfect and perhaps erroneous theory. We will correct with reluctance mistakes which result from ingenious conceptions and laborious investigation. The present subject in particular seems to encourage our researches by great appearances of success. But the convertibility of acids, which at first exhibited such uniform distinctions, should make us extremely cautious in forming general conclusions. I have not room to enter into a discussion of so many particulars. Nicholson gives the current opinions on the present subject with great candour and distinctness.

Thus we have considered the consequences of mixing spirit of wine with alkalis and acids in different ways.

Of the compound salts, there are a few which can be dissolved in this spirit; though the greater number cannot. The soluble are, the muriats of lime and magnesia, acetite of potash, the acetite and nitrat of ammonia. The rest, in general, are not soluble; but, on the contrary, are precipitated by it from water. Hence it is that the fixed alkali which is dissolved in vinous spirits, in the process for rectification, is of the utmost purity. Mr. Woulfe employs this method for examining their purity.

Vitriolated tartar, after long digestion with vinous spirits, exhibits some remarkable appearances. We obtain æther, sulphurous acid, and volatile alkali.

None of the earthy substances have any remarkable action on vinous spirits.

Phosphorus unites with it imperfectly, but without any phenomenon very interesting to the chemist. Mr. Boyle may be consulted on the subject.

Sulphur does not unite, even by long digestion. Count Lauraguais combined them perfectly, when in the form of vapour, issuing from two retorts. They form a fætid liquor.

Charcoal speedily clears spirits of wine from all distinctions of flavour, and makes all alike, and quite colourless.

VI.....OILS.

UNDER this division I comprehend, along with what are commonly called OILS, the solid fats of animals, and resins of vegetables, as being distinguished only by a slight difference in fusibility from the fluid inflammable substances of vegetables and animals, to which the term *oil* is in common language confined.

The bodies which belong to this division are far inferior to alcohol in simplicity and inflammability. Yet, when their inflammation is properly excited, they give more heat and light than alcohol does. They are, therefore, stronger fuels, or may be considered as more inflammable substances than alcohol is. And yet they are not (many of them at least) quite so easily set on fire, or brought into a state of inflammation. Most of them require to be heated more: and their inflammation in ordinary circumstances is not so complete. Their flame commonly throws out from the top of it a quantity of sooty matter, called lamp black, the inflammability of which is not exhausted. I call it sooty matter; but it is a matter considerably different from common soot, which is an article of the materia medica. This consists partly of lamp black, or the half burnt oily matters of vegetables, and partly of many other substances, not inflammable, which are volatilized and expelled by the heat, along with the inflammable vapours. Soot generally contains an ammoniacal salt, formed of the volatile alkali, existing or generated by the heat, in the vegetable, and an empyreumatic acid of the acetous kind. Lamp black is a less complex substance, being the scorched or half burnt oily vapour; and is always produced when the flame is of such a large size, or of such a form, that the air has not a sufficiently extensive contact with it to act with full power on the whole of the vapour that composes it. But when the flame is of a small size, or when a stream of air is made to rise up through the middle of it, as in Argand's lamps, or when a small stream of air is forced through it with the blow-pipe, the formation of soot is effectually prevented. I observe, however, that even a very small and clear flame from oil, without the least appearance of soot,

carries up a minute portion of whitish earth, which, during a long continued process with a lamp furnace, attaches itself to the bottom of the vessel that is heated by the flame. This is certainly part of the ashes, not volatilized, but merely blown out by the stream of vapour.

The component parts of oils are best discovered when we gradually convert them into vapours, and cause those vapours to pass immediately through a red hot tube, without mixing with air, into a proper apparatus for collecting gases. The result of this operation is the production of an immense quantity of *hydrogen gas*, mixed with some *carbonic acid gas*, and a small quantity of *watery vapour*. And in the tube and distilling vessel, when they are allowed to cool, we find a portion of charcoal, which, when burned in the open air, yields a small quantity of ashes, and a still smaller of saline matter, commonly fixed alkali.

This analysis, therefore, shews that the constituent principles of oils are *hydrogen* and *carbon*, with a small proportion of oxygen, and a still smaller of earthy and of saline matter. The presence of the oxygen is evident by the appearance of the carbonic acid, which is formed by the union of that principle with a part of the carbon, and also by our procuring a small quantity of watery vapour, which it forms by uniting with some of the hydrogen. The hydrogen gas obtained by this operation is necessarily of that kind which contains a small quantity of carbon dissolved in it, and which, on account of its being rendered denser by this admixture than a pure hydrogen gas, is therefore named *heavy inflammable air*.

When the oils are subjected to the treatment which was named **CHEMICAL ANALYSIS**, by the elder chemists, in which they were merely distilled in retorts and receivers, and the vapours of them thus condensed as fast as they were formed, and without being ever made red hot, the products obtained are considerably different; for this reason, that the principles of the oil are not so completely separated, from one another. The greater part of the vapours are condensed into an oil, or oily fluid, which has very different properties from those of the original oil. We procure also

some acid water, and some carbonic acid gas. And a small portion of charcoal remains in the retort.

Repetitions of the same process, with the same oil, diminish the quantity of the oil every time, rendering it more attenuated and volatile, and produce a little more water and a little more charcoal. And Mr. Lavoisier discovered that more water was produced every time from the same quantity of oil, when the distilling vessels were of a large size than when they were small. He therefore concludes that all this water did not pre-exist in the oil, but was formed in the distilling vessels from the hydrogen, which, uniting with the oxygen of the air contained in the vessels, formed the water, or a great part of it. And the acid found in this water, and which is of a peculiar kind, is undoubtedly formed of a part of the oxygen, loosely combined with a part of the hydrogen and of the carbon, as it is in the vegetable acids. Dr. Crell of Helmstadt made a very satisfactory set of experiments to investigate its peculiar properties. They are published in the 70th volume of the Philosophical Transactions. This acid is now named the *sebacic acids*: and the compounds it forms with alkaline substances are named *sebats*.

The consequences are different when we apply heat to the oils in the open air, so as to inflame them in the most perfect manner. The whole of the hydrogen and the carbon unite with the oxygen of the atmosphere, and form water, or vapour of water, and carbonic acid in an elastic state.

I have long been of opinion, that a great quantity of water arises from burning oils. A plate of very cold glass or metal being held for a moment above a very small and clear flame, will immediately be covered with dew; and a bell glass held over the flame and kept cold by snow, will soon have drops of water hanging at its brim. But Mr. Lavoisier has collected this water more accurately and completely, by means of a well contrived apparatus: and he finds that it exceeds the weight of the oil. Something, therefore, supplied by the atmosphere must contribute to form it.

The only question is, whether this water has been existing previously in the air, or has been formed in the manner assigned by Lavoisier? The last is more probable; because

we cannot see how the heat produced by inflammation can make the air deposit water which it suspended when colder*.

If the inflammation be improperly managed, the change and destruction of the oil is not so complete. The soot which is produced from all oils, when we attempt to burn them with too large a flame, is formed principally from the carbon.

To treat of the oils more particularly, they must be distinguished into two principal kinds, the AROMATIC and the UNCTUOUS ; to which it is usual to subjoin a third section, named EMPYREUMATIC.

The *aromatic* oils are all formed by nature, and chiefly in vegetables. In these they are secreted juices, lodged in particular parts or repositories in the structure of the plant. All the aromatic oils make a strong impression on the organs of taste and smell, exciting on the tongue the feeling of heat and acrimony. And they have not that smoothness and slipperiness, when felt between the fingers, which is named *unctuosity*. They are also all capable of rising in vapour, in the heat of boiling water, or at least along with the vapour of water. And they are very inflammable. The wicks of candles are often prepared for being quickly lighted up, by putting a small quantity of some of these oils on the extremity of them.

The *unctuous* oils are also natural productions ; and are found in vegetables and animals, in both of which they are also secreted juices, or are formed and lodged in particular parts or repositories.

When not corrupted, they have not any pungent taste, or remarkable odour, but have unctuosity in a great degree ; and for that reason are much employed to diminish friction in machines of all kinds. The heat of boiling water is not sufficient to convert them into vapour : and they are not so readily and quickly inflamed as the aromatic oils.

* It is perhaps owing to this actual formation of dampness, or water, that Dr. Franklin found that all electrical experiments are almost stopped, while a burning candle is connected with the insulated part of the apparatus. We have the means of deciding this question....EDITOR.

The *empyreumatic* oils resemble the aromatic so much by many of their chemical qualities, that they are not distinguishable from them by any general difference, except the circumstance of their origin. None of them are natural productions. They are all produced by art; and are either oils, changed from their natural state by the action of violent heats, or are entirely produced by heat from vegetable or animal substances which do not contain a formed oil before the heat is applied to them. We may also add, as an article in the character of the empyreumatic oils, that the odour of them is in general offensive.

AROMATIC OILS.

LET us now take a nearer view of the first of these sections, the aromatic oils.

We find almost the whole of them in vegetables. There are a few examples of similar oils got from some animal substances: but they are very few. It is by examining vegetables that we find a great number and variety of these oils. All the vegetable substances which affect our organs with any remarkable odour, or hot pungent taste, produce these effects by the action of an oil, or oily principle of the aromatic kind which they contain.

And, as in a great number of such vegetables, these oils are the most remarkable, and the most useful and active matter which they contain, they are for this reason named the **ESSENTIAL OILS**, or **ESSENCES** of such vegetables.

The variety of them found in the different vegetables, or vegetable substances, is very great. But the greater number of them have not yet been found applicable to any useful purpose. And many others are contained in the vegetables in such very small quantity, that we cannot extract them except at a very great expence, far exceeding any value that can be set on them. Such, for example, is oil of roses, which has the fragrancy of that favourite flower in the highest perfection. Roses contain more of it in the warmer climates, and yet even in these, so little, that it is valued at an extravagant price. Some of this oil is collected in India, partly from rose-water.

The odour of these oils, which is in most of them strong and fragrant, is one of the most remarkable of their obvious qualities. And this odour is different and specific in each particular oil. But they are diversified by other properties besides the variety of odours.

Some of them are extremely fluid, light, subtile, and volatile. Others are more heavy and thick. And some are frozen in ordinary heats of the air. Many taste extremely hot, pungent, and acrid, when applied to the tongue. Some have a much milder taste. And it is difficult to give any general rule with regard to these qualities. It is very generally said, that the essential oils produced in colder latitudes are lighter than water; while those of the hot are so heavy as to sink in it. But this cannot be admitted as a general fact. The oil from parsley seeds sinks in water. There are too many exceptions to it, and the same oil does not always appear of the same density. Oil of cinnamon will float or sink, according as it has been drawn off by a gentler or a stronger heat. And I am inclined to believe that this inference, with respect to the weight of the aromatic oils of warmer latitudes, has been drawn chiefly from experiments made on the oils procured from the dry spices brought from the East and West Indies, in which the oil has grown thicker and heavier by age and evaporation, and by combination with oxygen, than it was in the recent and green vegetable.

All authors have observed, with regard to these oils, that it is difficult to preserve them long in perfection. The only way is to keep them in phials, with glass stoppers carefully ground to the phials, so as to shut them perfectly close. And further, it is proper to set them in a cool place. If these precautions be neglected, they are sure, after some time, to become less fragrant, less fluid, and generally to suffer a change of their colour. These changes happen to them more quickly when they are exposed to the air; and, in this case, a part of them commonly evaporates at the same time. These particulars, therefore, shew that the depravation they suffer, if kept with too little care, proceeds, in part at least, from exhalation of their more subtile and volatile part, upon the presence of which their odour and tenuity chiefly depend. This is confirmed by the nature of the operation which has been found most proper for restoring again to a state of per-

fection some part at least of the oils which have suffered this depravation. This operation is to subject them to distillation, along with some water, so that a part of the water and oil may distil over with gentle heat. These oils, when recent and in perfection, are, in general, very volatile. Oil of sassafras, for example, if dropped on a bit of paper, and held over a candle, at a great distance, will quickly disappear, leaving no stain. They evaporate slowly if exposed to air. And when the heat of boiling water is applied to them, they emit visible steams, and evaporate copiously. This volatility they shew most remarkably when freshest and in greatest perfection. When old and ill kept, we do not find them so volatile; at least it is not so easy to evaporate them entirely. But if such depraved oils be put into a retort with water, and part be distilled off, the part distilled is found to be much improved, and what remains in the retort to be grown worse; that is thicker, heavier, darker, and less odorous. If the distillation be not too long continued, the portion distilled is equal in goodness to the oil in its recent state. By this operation, therefore, we recover, in a state of perfection, one part of our depraved oil. And if it be repeated several times, we increase the tenuity and volatility of it, even beyond the natural or more ordinary state; but, at the same time, we still diminish its quantity so much the more.

Mere loss of some of the more fragrant part, is not, however, all the change which the aromatic oils sustain by exposition to the air. They actually combine with the oxygenous portion of atmospherical air. This was observed very early by Dr. Scheele and Dr. Priestley. The thickening of oils and resins was one of the most effectual means of phlogisticating the air in Priestley's numerous and important experiments, and indeed one of the most specious arguments for his opinions. The oil exhaled its fragrant ingredient, which was thought replete with phlogiston. The air was rendered unfit for the support of flame. Scheele, however, drew a more warrantable conclusion. He saw that the air was diminished in the same way as by the absorption of hepar sulphuris. Therefore, he inferred that the *fire-air* was absorbed, and that the mephitic portion of atmospherical air alone remained. He ascribed the change on the oil

AROMATIC OILS.

to this combination. This has at length been evinced by clear experiments in some few cases, in which the weight of the inspissated oil was found greater than that of the fresh oil. When exposed in vital air, the change is much more rapid and remarkable. The fact is no longer doubted.

When we try how these oils are affected by mixture with other bodies, we find, in the first place, that they can be combined in small quantity with water, by churning and maceration. By this operation, the water acquires a good deal of the flavour, and still more of the acrid pungency of the oil. But it does not contain any sensible portion of it, nor does the oil lose any weight. The mixture can scarcely be called a chemical combination; for the water is soon covered with a shining film, which thickens by exposure to the air (probably by absorbing oxygen); and the water in a short time loses the greatest part of the pungent taste it had acquired. If a small quantity of this water, while fresh made, and quite limpid, be agitated in a large vessel filled with vital air, it becomes milky immediately, and much air is absorbed. It would seem that it is this portion, so miscible with water, that acts the most powerfully on oxygen, and combines with it.

Of the salts, the alkalis have a disposition to unite with these oils. A composition of this kind has long been described by chemical authors under the title of *Starkey's soap*, formed of oil of turpentine, or of juniper, and the alkali of tartar. But they speak of much difficulty attending the process. This difficulty, however, proceeded from their taking the alkali of tartar in its ordinary state. Dr. Crell found that caustic fixed alkali readily unites with the oil. This combination has not been much studied, except for medical uses: and it does not seem to be of much importance in this respect.

Combinations or mixtures of the volatile alkali also with these oils are formed for the purposes of medicine, on account of their having some medicinal powers similar to those of volatile alkali, viz. cordial, stimulating, and antispasmodic. We have examples of such combinations in SPIRITUS VOLATILIS OLEOSUS, and SPIRITUS VOLATILIS FOETIDUS, and EAU DE LUCE.

When the nitric acid, in a concentrated state, that is, having as little water as possible combined with it, is suddenly mixed with any inflammable body, its oxygen is so loosely combined, and retains so much of its latent heat, that it is immediately acted on, and its heat is extricated by combining with that body. If the substance be fluid, so as to allow an extensive surface of action, and not so volatile as to be dissipated in vapour at the first warming, the heat produced may increase to ignition. This is remarkably the case with the aromatic oils. Besides this, they shew a remarkable disposition to unite with oxygen. They are thickened by exposition to the atmosphere, as has been already observed, and this is attended by an absorption of vital air. They have also a low temperature of inflammation.

For all these reasons, when nitric acid is poured into an aromatic oil, such as oil of cloves, or oil of turpentine, the mixture generates heat, boils up with great violence, and bursts out into flame. When this phenomenon was first observed, it was seen that a strong acid was necessary, and as the process for the *spiritus nitri fumans Glauberi* is particularly directed to every circumstance that can ensure its concentration, this smoking acid was always employed: and it will always succeed, if the concentration be as perfect as we suppose. But you have seen that a very fuming spirit may be had that contains much water, merely by dissipating some of the active ingredient by a little vinous spirits, sugar, or such like. Strong, pale, or nitric acid will much more surely produce the required effect. The manipulation prescribed by Dr. Stare is also very proper, viz. to pour in about half of what we ultimately intend, and in four or five seconds after, to add the rest at once. When the heat produced by the first is at the height, and has expended part of the strength of the acid, we then add a parcel in its full force. Nor is the mixture of a little very strong sulphuric acid improper. This quickly generates a most inflammable vapour (sulphurous) which catches fire the more readily, as it meets with so much loosely combined oxygen in the nitrous acid. Nay, the sulphuric acid alone, if clear and strong, will inflame the heavy aromatic oils, such as the oil of cloves,....and frequently too, in favourable circumstances, even oil of tur-

pentine. The mixture, when it does not kindle, acquires by long digestion qualities which greatly resemble the bituminous oils and solid bitumens. If the acid has been diluted, the mixture has a soapy appearance, mixing pretty intimately with water.

Even the muriatic acid may be combined with oxygen (by a process which will soon be explained to you) in so abundant and loose a manner that it will fire the aromatic oils with great readiness.

The neutral salts have no action on essential oils in mixture without such heat as to burn them. Nor have any of the earths except quicklime. By long trituration it renders them miscible in some measure with water; and is thought to dispose them to a more ready yielding their most odorous part by distillation.

Essential oils unite with sulphur very readily, and compose balsams of sulphur, drugs of a very disagreeable smell and taste, which have remarkable effects on the nervous system. The vapours are highly inflammable. They also dissolve phosphorus: and the compound becomes luminous by coming into contact with the air, and takes fire in very low temperatures. The warmth of the hand is in many cases sufficient.

They are dissolved by alcohol; but are separable by water, and in some measure also by distillation. When we distil the alcohol, however, from an aromatic oil or vegetable, the more subtile and fragrant part of the oil generally rises with the spirit, if a very gentle heat be employed. On this account, the odorous spirits distilled from them may be so prepared as to have a more subtile and delicate flavour than the odorous waters derived from the same oils; because the heat of boiling water considerably exceeds that of boiling alcohol. Thus are formed, from some aromatic oils or aromatic vegetables, the compound spirits and cordials of the apothecaries. Brandy is the spirit commonly used. Some of the finest perfumes are also prepared in this manner. (*See Beaumè.*)

Such is the general nature of the aromatic oils. There are a few, however, which differ so far from the rest as to require some notice of their particular qualities. These are distinguish-

ed by the appellation of CAMPHORS. But there is only one species commonly known, and which is always suggested by that term; the others not being in use. The species I mean is that commonly used in medicine. It is procured from a tree of the laurel kind, and has these qualities:

First, it is, like the other aromatic oils, highly inflammable, burning with a most brilliant flame, but producing a good deal of soot. It leaves no ashes whatever. It will burn on the surface of cold water. It is dissolved in small quantity by hot water, and imparts to it its taste and odour. It is readily soluble in alcohol, and separated by water. In all which respects it resembles the rest of the essential oils. It is particular by being always solid. When dissolved in alcohol in great quantity, it crystallizes by evaporation of the alcohol, as also when it is slowly separated by water, when the spiritous solution is set in a cold damp place. When heated, it does not melt, but evaporates, and sublimates in beautiful crystals. And this it does more readily and completely than the other aromatic oils, never leaving, when pure, the smallest matter behind. It is therefore one of those bodies which are more volatile than fusible under the pressure of the atmosphere. But by confining it much, it may be melted *.

The relation of camphor to acids is more remarkable. It is dissolved by the sulphuric and nitric acids, but without violence; and with the last it forms a fluid which appears like oil. Heat applied to this oil occasions the acid and camphor to act on one another. And the acid is imperfectly decomposed, and gives out red vapours. By repetition of this process, the camphor itself is changed into an acid which has peculiar properties, resembling those of the acid of sorrel. Its properties have not been much examined, the preparation of it being very expen-

* In the process for refining camphor, it is set in a sand heat, in very low flat matrasses, shaped like a flat turnip, and having a short neck about an inch and a half in diameter. This is shut by a bit of paper loosely twisted. In this situation I saw it boiling like water. The cake of sublimate formed very vast; and though the vessel may be said to be open, and more than a hundred were on the furnace, there was only a very moderate smell of camphor in the laboratory....EDITOR.

sive, and requiring eight distillations with fresh nitric acid. But it quickly loses this appearance by the application or contact of pure water to it, which immediately attracts the acid from the camphor again.

This habit of camphor in relation to the acids, especially the nitric, is its most distinguishing quality. This acid acts with such violence on all inflammable substances, and particularly on the aromatic oils, and camphor being so eminently inflammable, we should expect very different phenomena. The nitric acid suffers none, or almost none of the changes which result from a separation of oxygen. There is, therefore, something very peculiar in the constitution of camphor :.... but it is of difficult investigation. For, when a strong heat is applied to it, it flies off unchanged, and crystallizes in the first cooler place it comes to. Many chemists think that camphor is the principle of aromatic oils and of resins; but on what grounds I know not.

There is only one species of camphor used in medicine, or found in the shops. But there are several kinds, which may be obtained from different vegetables, and even from some aromatic oils already separated from the plant, all of which have the properties I have now described, and differ from one another only by odour. Newmann gives experiments and examination of a camphor which crystallized from the oil of common thyme. And he enumerates the roots of the cinnamon tree, zedoary, schœnanthus, cardamomus, oriental mint, abrotanum, milfoil, daisy, juniper, rosemary, salvia camphorata, lavender, hyssop, clary, maudlin, marjoram, &c. I am informed that it has been obtained lately from the leaves of the pimento, or Jamaica pepper tree. If so, we may soon expect it in great abundance, that being a very common tree, with exuberant foliage. Camphor is obtained from all these matrices much in the same way as from the *laurus camphora*, namely, by maceration in water, and then boiling the materials in an alembic, having the head occupied by loose straw. A good deal of the camphor sublimes, attaching itself to the straws: and the rest goes over with the vapours into the receiver.*

*.From some trials, I am disposed to think that both the wood and the leaves of the pimento, or Jamaica pepper, will yield a very good camphor

As camphor is different from the rest of the aromatic oils by these chemical properties, it is remarkably distinguished from them also by its medicinal qualities, being much less heating and stimulating than the essential oils; though at the same time it has great powers as an antispasmodic, an antiseptic, and a diaphoretic. By its being free of the heating quality, it is safe and useful in a great number of diseases in which the other aromatic oils are improper. But we must not give it in such large doses as are said by Mr. Fourcroy to be given in England. Two scruples at once are not safe, except perhaps in mania. (*Vide Dr. Alexander's Experiments.*) Applied externally, in ointments or other forms, it is very powerful in discussing or displacing rheumatic pains. But there may be cases in which this use of it may be improper, as in external rheumatic pains of the thorax, unless other remedies are employed at the same time.

I may add, that when burning, its light seems to be the same, or to consist of the same proportion of coloured rays, with that of the sun. All delicate colours, which appear different in candle light, appear of the proper colour when illuminated by camphor.

And now I have said enough of the aromatic oils. The manner of extracting them from the vegetables which contain them, is so fully described in every book on chemistry and pharmacy, and it is so commonly known and frequently practised by the apothecaries, that I need not take up much of your time with it here.

The most common operation by which they are extracted is distillation of the vegetable with water. A quantity of the aromatic vegetable is put into a common still, with as much water as floats it or covers it; and the distillation is begun immediately, or after a day or two. The hot water penetrates the vegetable matter; softens it; and dissolves more or less its aromatic parts, so as to disengage the oil in some measure. And while the distillation goes on, the oil is changed into vapour, it is even deserving of serious trial, because camphor would be very extensively used in several manufactures if cheaper. The pimento is so abundant in the West Indies, that it would cost nothing....EDITOR.

along with a part of the water ; which vapour of the oil is carried over with the vapour of the water into the refrigeratory. Thus the oil is distilled over faster than it could be with the same heat by itself ; while, at the same time, the water prevents the vegetable, or the oil, from ever becoming hotter than 212° Fahrenheit, which it would certainly do, were it exposed to heat by itself. And experience has shewn, that these oils are the more fragrant in proportion as they are obtained with less heat.

The oily substances called **BALSAMS** and **RESINS** belong to the same division with the aromatic oils, and resemble them very much by their principal qualities. They are found in a number of vegetables, and, like the aromatic oils, are secreted juices, deposited in particular spots, or particular vessels of the plants. They are in general more or less odorous substances, and also produce the sensation of taste, with more or less pungency and heat. They are all very inflammable, and burn with the same phenomena as aromatic oils, only they give more soot, and more fixed carbonaceous matter. Infused in water, most of them impart to it some taste and odour. They are affected by acids as aromatic oils are. They dissolve with ease in spirit of wine, and are separable from it again by water. So that you may imagine I am describing the aromatic oils.

The chief distinction is the degree of fluidity and volatility. Balsams in general are not so fluid or volatile as aromatic oils ; and as there is great diversity among them in the degree of these qualities, there are many that are commonly solid, and even considerably hard. The terms of balsam and resin refer only to differences of this kind. The greatest part of what are called balsams have a sensible degree of fluidity, and some are almost as fluid as some of the thicker oils. Resins are solid and brittle in the ordinary temperature of the air. But if heat be applied to them, they melt into a viscid oily fluid, which, so long as it is melted by a gentle heat, is not distinguishable from what is called a balsam. But the balsams themselves vary greatly in consistence by age. By the evaporation of their more volatile and odorous parts, they always become more solid, and even hard.

These substances in general are more disposed than aromatic oils to unite with alkaline salts. And it appears that soap-boilers have found it their interest, for some time past, to employ a proportion of common resin in the composition of hard soap, by which they render it much more deterfive.

Besides these differences of balsams and resins from the aromatic oils, I just now said that they are less volatile. This is true, however, with respect only to the greater part of their substance. When balsams and resinous substances are exposed to the heat of boiling water, or rather, are boiled with the water, they are always in part converted into vapour, and disperse their odour around. Of many, a very considerable part rises along with the vapour of the water. This volatile part, when condensed in distillation, is a perfect aromatic oil. And the part which remains in the distilling vessel is a resin, which becomes solid and brittle when cold, and is far less odorous and volatile than before. We have an example of all this in turpentine. If it be submitted to distillation without addition of water, we first obtain from it a quantity of an aromatic oil, similar to that which arises when it is distilled with water. But before it has all arisen, the resinous matter becomes too hot; for it is capable of being heated to a much higher degree than that of boiling water. The heat, therefore, accumulates in it, and soon begins to decompose and destroy it; in consequence of which it is changed into a species of empyreumatic oil, and a small portion of water, and of vegetable acid. And a charcoal remains in the retort, in greater quantity than that which is produced from the aromatic oils when they are treated in a similar manner.

It is worthy of remark, that when we distil turpentine with water, the produce of the distillation, together with the resin in the retort, weigh considerably more than the original turpentine. The resin and the oil are immiscible with water. Water has, therefore, been so combined as now to form part (nearly one-sixth) of the oil. Observe also, that the oil is vastly more odorous than the turpentine. This in some measure explains how effete aromatic oils are improved by distillation with water.

There is a considerable number of vegetables which contain balsams, or resins, all distinct and diversified from one another. And some have been found useful in medicine, and in the arts. Their powers in medicine are, in general, similar to those of the aromatic oils: but they are not so heating. In the arts, they are employed in varnishes, paints, and perfumes, and other such compositions; also in natural history, for preserving insects.

Those ordered by the colleges of London and Edinburgh to be kept in the shops are,

TEREBINTHINA *Chia, sive Cypria.* Lond.

Veneta, (Ed.) From the larch of the Alps and Pyrenees. A kind from New England generally supplies its place in the shops.

Argentoratensis, (Lond.) Strasburg turpentine, prepared in different parts of Germany, from the firs which are native and most common in England and Scotland.

BALSAMUM *Canadense*, (E.) Another fir in America, the Virginian, or Canada fir-tree, yields a turpentine much superior, brought over under the name of *Balsamum Canadense*.

BALSAMUM *Commune*, (L.) The coarsest, &c. from the *pinus sylvestris*, common in different parts of Europe.

Copaiba, (L. and E.) From the Spanish West-Indies.

OPOBALSAMUM....*Balm of Gilead.* The best kind exudes from the plant in Arabia; but is never seen in Europe. The inferior is separated from the leaves and branches by light boiling in water; but is also extremely scarce, so as to be hardly procurable.

BALSAMUM *Peruvianum*, (L. E.) From an odoriferous shrub in Peru, and the warmer parts of America, and extracted by coction. It does not unite with water, milk, unctuous oils, or wax. There is another balsam of Peru, of a white colour, and more fragrant, said to be procured by incision.

Tolutanum, (L. E.) From a tree of the

pine kind in Tolu, Spanish West Indies, and brought in little gourd shells.

BENZOINUM, (L. E.) The juice of a large tree, in both Indies, and bearing our winters. But the benzoin is brought from the East Indies only. It is used chiefly as a perfume. Water extracts very near as much of the flores by coction as is obtainable by heat.

GUMMI *Guaiaicum*, (E. L.) Procured by incision from a tree in the warmer parts of the Spanish West Indies.

——— *Animé*. A resin, procured by incision from a large American tree. It dissolves totally, though not easily, in spirit of wine, and has a transparent amber colour.

——— *Elemi*, (L.) A resin, brought from the Spanish West Indies, and sometimes from the East Indies. It distils with water, gives a fragrant oil, and deserves more notice.

——— *Hederæ*, From ivy.

GUMMI *Juniperi*, Exudes from the juniper, in warm climates.

SANGUIS *Draconis*, Brought from the East-Indies.

SAGAPENUM, (L. E.) A concrete juice from Alexandria.

LABDANUM, (L.) Exudes upon the leaves of a small shrub in Candia, and other islands of the Archipelago: and is brushed off with a sort of rake, with leathern thongs for teeth. It sticks to the thongs, and is afterwards scraped off. It is mixed with much sand, and does not bear separation by extraction, without diminution of its fragrancy.

I observed before, that the balsams and resins are secreted juices in the plants which afford them. Many are collected by bleeding or extravasation, at natural or artificial wounds, as turpentine. Others are an exudation or excretion from the surface of the leaves or other parts of the plant, as in the moss rose, and labdanum. Others are obtained by boiling gently with water. And some resins are extracted from dried vegetable substances by the application of alcohol, and

separated from the alcohol afterwards by gentle distillation, or by the addition of water.

And now I have given a description of the balsamic and resinous substances, which is general, and applies to all of them except a few species. In all parts of nature, we find her productions so greatly diversified, that it is impossible to give general characters and descriptions that will suit every particular. There are always some species, which must be considered as exceptions from the general nature of the rest. In this light must we view three or four resinous or balsamic substances, which I shall now mention. These are copal, benzoin or benzoe, and ambergrise.

1. COPAL is very transparent, and considerably hard, and is not dissolved, but only softened by alcohol. This distinguishes it from gum animé, which resembles it perfectly in external appearance. But it can be dissolved by some of the aromatic oils; and thus forms the most beautiful and durable varnish employed in the arts. It was invented in France, and long known by the name of *vernîs Martin*. In England it is called copal varnish, and is highly prized for its horny toughness. The art of preparing it is not commonly known.

When copal is treated with oil of turpentine in a close vessel, from which the vapours are not allowed to escape, they exert a great pressure, which prevents the boiling; and the mixture acquires a higher temperature. A very considerable portion of copal is dissolved: and with the addition of a little poppy-oil, it forms an excellent elastic varnish, inferior to the *vernîs Martin* only in a tint of brownness, scarcely perceptible.

Another good elastic varnish is made of copal, by keeping it melted till an acid or sour-smelling aromatic vapour has ceased, or become scarcely sensible. It must then be mixed with an equal quantity of lintseed oil, which has been deprived of all colour by long exposure to the sun's light. The varnished ware must also be dried in the sun.

2. BENZOIN is obtained from a tree in India, and is a balsamic substance of the more solid kind. It differs remarkably from most other balsams by the nature of its volatile

part. It is not an aromatic oil, but a substance of a very peculiar kind.

Benzoin is commonly in the form of tears, like other resinous exudations. It is very fragrant when hard rubbed, or when touched by a hot iron, or if sprinkled on a hot plate; and is much used on the Continent for incensing a room.

When merely heated, it swells up and becomes very fragrant: but when thrown on hot coals, it burns violently, and the odour is too piercing. If slowly heated in a low pipkin, on which a cone of paper is fitted, a vapour arises from it, which collects on the inside of this cone in fine white spicular crystals. These are equally fragrant, but provoke coughing. They are very acid, with some pungent bitterness. This is *flowers of benzoin*, or the *benzoic acid*.

The same crystalline acid matter may be obtained by boiling powdered benzoin in a great deal of lime-water, evaporating to a small quantity, and then detaching the lime by muriatic acid. The benzoic acid then crystallizes.

This is a singular substance, holding a sort of middle rank between the aromatic oils and the salts. For it is highly fragrant, and inflammable, yet truly acid, uniting with all alkaline substances, and with the metals. It seems to maintain its character more firmly than any other vegetable acid. For it dissolves in the vitriolic and the nitric acid quietly, and without inducing that change which they suffer from the loss of a part of their oxygen. The nitric acid emits some faint ruddy fumes indeed, but without effervescence or commotion. A very small quantity of water added makes the compound of nitric and benzoic acids float on the top like an oil: but a little more separates the latter in filaments, and unchanged in its properties.

Benzoin, like other resins, dissolves in alcohol, and is separated by water.

3. AMBERGRISE differs from the other balsamic or resinous substances chiefly by its origin. The greater part of what is brought to the market is found floating on the sea, sometimes in the northern parts of the Atlantic Ocean, but more frequently in the Indian Ocean, where it is sometimes found adhering to the rocks on the coast. For a long time, very different opinions were formed of its origin. It was supposed

by many to be a fossil substance, which had been washed out of its original place by the waves. More lately, it was alleged to be the production of a tree in America, from which the ambergrise issued as the balsams do from other plants, and that it was carried into the sea by rivers. Had this been true, we should have heard of this tree long before now, and got the ambergrise from it. The latest opinion is, that it is formed in the body of an animal. There are many reasons for believing that ambergrise is really formed in that species of whale called the *physeter macrocephalus*, or *bottlenose*: 1st, Masses of it have been found in the bowels of the animal: and though it has been alleged that the animal, which is very voracious, had in this case found it in the sea, and had swallowed it, this is a mere supposition. 2dly, There are often found mixed with it, little bones of fish, and beaks, and feet of the *sepia*, or *cuttlefish*, which is known to be eaten by that whale. 3dly, The substance of the ambergrise is of a brown colour, and has a consistence like that of bees wax, but contains numerous white grains which are calcareous. This does not occur in any vegetable production. 4thly, A small mass of ambergrise, which I saw in Apothecaries Hall at London, was like a gall-stone. It had evidently a sort of nucleus, surrounded with thick concentric layers. I am therefore inclined to suspect that it is a morbid concretion, formed in some part of the alimentary canal of that animal, or in some cavities which communicate with it, in the same manner as the gall-stones are formed in other animals.

We may further add here, that substances remarkable by a strong odour, are produced in a similar manner in several animals. Such are musk, civet, and castor. And there is in dogs a similar matter, which has an insupportable heavy smell; and in insects, of different kinds, as bugs, &c*.

That ambergrise, though an animal production, must be considered as a balsamic or resinous substance, appears from its

* There is a kind of whinstone rock on the coasts of Scotland, and also on the north shore of the Frith of Forth, which has many small cavities, about the size of small pease, or pin-heads, many of which are filled with a substance having the colour, consistence, odour, and chemical qualities of ambergrise.

properties. It has an aromatic odour, and it is volatile by heat, though not so volatile as aromatic oils. It is also soluble in alcohol. Its general appearances, however, more resemble those of the bitumens.

MUSK, CIVET, and CASTOR, cannot properly be called either oils, balsams, or resinous substances. They are animal concreted juices, prepared by secretion; but they contain an aromatic oily principle, which gives them their odour, and which rises in distillation with water. The quantity of it, however, is small, or the nature of it such that it cannot be collected by itself in form of an oil, but remains combined with the distilled water.

Before we dismiss the consideration of balsams and resins, I must observe, that the term *gum* is often, and very improperly, applied to many of them in pharmacy; as to copal, gum-hederæ, guaiac, juniper, animé, elemi, benzoin. When the term gum is used with propriety, it is applied to substances totally different in quality from resin. A gum is indeed a juice which exudes from plants, but it dissolves in water, and not in spirit of wine. On the contrary, it is separated from water by spirit of wine. And it has no more inflammability than any other vegetable substance. Gum-arabic is an example.

There is still another set of products of vegetables to which the term gum is improperly applied. They are likewise inspissated juices. Experiments shew them to be composed of a mixture of gum with resinous, balsamic, or oily substances. Such mixtures are gum-ammoniacum, galbanum, sagapenum, asafœtida, opium, and several others. The proper name for these is GUM RESINS. By applying alcohol, we dissolve the resinous or oily part, and leave the gum. Water, on the other hand, acts chiefly on the gum, and but very imperfectly on the resinous or oily part. I say no more at present on this subject. We are to treat more of these things when expressly considering vegetable substances; as gum is a merely vegetable substance, which does not properly belong to any of the five classes of the objects of chemistry.

As among the resins, so among these gum resins, there are some distinguished by their peculiar nature or useful qualities. Such, for example, is the substance called LAC, or GUM-LAC. It is produced from the extravasated juice of some trees in India.

when they are punctured by a small insect in their tender new branches or shoots. The insect is a *coccus*. The lac itself has all the chemical qualities of a resin. It is of a deep red colour,and makes the basis of the finer kinds of sealing wax, and of many varnishes. The natural history of this substance, and of the insect which occasions its production, is curious. (*See Phil. Trans.* 1781.)

The American concreted juice, called by the natives *cahoutchouc*, is also a singular substance, which I think belongs to the gum resins. It is the milk of a tree. It shews that it contains a gummy or mucilaginous matter by the effect of warm water upon it, which softens it, and makes it swell. And the resinous or oily principle in it appears by the action of the sulphuric æther, and by its inflammability. It is used for rubbing out pencil lines,....for injection bottles....to form boots, port-manteaus, flexible perforated bougies, &c. But the manufacture of it is as yet extremely imperfect*. We get it in the form of little bottles. These are formed by receiving the milk of the tree on clay moulds, by repeatedly smearing them over with the exudation, and drying each coat by a wood fire, the smoke of which gives it the dirty brown colour. When all is dry, the moulds are crushed and washed out.

This substance melts, but without forming a perfect fluid. When cold again, its texture is quite changed, and its tenacity and elasticity are gone. It burns with violence and much smoke, and leaves much coal.

No solvent has yet been found from which it can be separated in an elastic and uniform state. Nitrous æther dissolves it, and may be evaporated from it, but leaves it filamentous like paper or washed leather, permeable to water. Vitriolic æther, saturated with water, is said to soften it so that it can be easily joined in any way. The inspissated juice of the fruit of the briony, has a considerable resemblance to *cahoutchouc*; as also the juices of some plants which grow in the East Indies, such as the *ficus Indica*, and a plant described in the *Asiatic Researches* under the name of *urceola elastica*.

* An ingenious chemist of Glasgow has discovered a method of expanding it to any size and thinness, as glass is blown.....EDITOR.

UNCTUOUS OILS.

THESE are very commonly called EXPRESSED OILS, from the operation by which the greatest number are extracted from the vegetable or animal substances which contain them.

Under this title I comprehend the solid fats of animals, which are but little different by their chemical qualities from the unctuous oils of vegetables: and there are vegetables which contain unctuous oils as solid as the animal fats.

These oils are distinguished from the aromatic by being mild, free of taste and smell, and feeling unctuous or greasy between the fingers: and besides, they require a much stronger heat than that of boiling water to convert them into vapour; and they do not take fire so readily as the aromatic.

They resemble one another upon the whole, more than the aromatic do. They are more nearly of the same gravity, being all lighter than water. And the greatest number of those which are commonly fluid, are sluggish and thick, compared with many of the aromatic.

As the unctuous oils, in their perfect state, have no sensible odour, and are far less volatile than the aromatic, they do not soon suffer any remarkable loss or evaporation by exposure to the air, nor undergo the same change with the aromatic. But, in certain circumstances, they are liable to another sort of depravation, called *rancidity*. This appears when they have been too long kept, especially in a warm place, or in warm weather. They acquire a thicker consistency and offensive smell, and a great degree of acrimony, or at least a power to irritate the nerves of delicate stomachs with very great violence. The beginning of this sort of corruption is generally attended with a diminution of the colour of the oil. Thus, the fine oil of olives, when fresh imported, and perfectly sound, is of a strong and bright yellow colour. When it begins to grow rancid, it becomes colourless, like water: and this is the case with many others. The nature of this corruption has not yet been examined or explained. But I believe it depends upon an incipient resolution and separation of the principles of the oil from one another. I

know that oils, in a high state of rancidity, generate slowly inflammable vapours. Bellows of an iron finery were often burst by the firing of an inflammable air produced within them from the oil with which the leather was anointed. This rancescence seems chiefly owing to an extractive mucilage which unctuous oils contain; for one way of preventing or greatly retarding it, is to churn the oil with a great deal of warm water, repeating this operation till it comes off perfectly clear from the oil. This change in the mucilage seems a fermentation, occasioned by absorption of oxygen; for Scheele observed, that oils becoming rancid absorb and spoil air: and it has been since found that these oils become much sooner rancid in vital air. Oils and butter have been kept in water for fifty years perfectly sound.

We find a great difference between these oils and the aromatic, in their disposition to be affected by heat. I observed before that they are not near so inflammable; nor have they the least degree of volatility in boiling water, nor even in degrees considerably above it. Most of them contain a little humidity and mucilaginous matter, which, when the heat rises above that of boiling water, produces a little crackling and boiling. But this is soon over, and then the oil is capable of being heated to 400 or 500 degrees. But, as the heat increases, they begin to emit vapour and smoke, acrid and offensive to the throat and eyes. The remainder becomes thicker, and darker coloured, and capable of receiving more heat: and the vapour and smoke become thicker, until at last they break out into flame. But before this, the oil is so hot, that tin and lead very easily melt in it; and it is nearly as hot as mercury boiling.

In many employments of the fat oils in the arts, it is necessary not only to clear them of the water they contain, but also to give them a boiling heat, which acts on some of their principles, so as to produce changes which fit them for particular purposes. As this heat is near to that in which they catch fire, the operation is frequently performed out of doors. If, in this condition, a shower of rain falls, there is great danger of the oil being dashed out of the vessel. If it falls from a height, it penetrates to some depth, where it is blown up into bubbles of elastic vapour, and it explodes, dashing the oil about on all sides. But

beside this, it is discovered that water is decomposed by oils in this temperature, and a vast quantity of *inflammable air* is generated. One drop of water will produce above an English pint. This is the chief cause of the explosion, and increases the danger by its inflammability. Great heat is necessary for this action.

When we simply distil these oils in a retort without addition, the greatest part distils over, in the form of an oil, quite changed from its natural state. It has acquired a brown or black colour, and a penetrating offensive smell, mixed however with some fragrance, and an acrid taste. It is now become one of the *empyreumatic* oils, which are soon to be described. The quantity of it is somewhat less than that of the oil before this operation: but the deficiency is made up by a portion of water obtained at the same time, and into which a part of the oil is changed, as I formerly observed. In this watery fluid is found the sebacic acid of Crell.

By trying to mix the unctuous oils with other substances, we learn, in the first place, that they do not communicate any taste or other sensible quality to water, as the aromatic do; nor can they be dissolved in alcohol. But they can be combined readily and intimately with the alkalis, and form with them perfect SOAPS, which can be dissolved, either in water, or in a mixture of water and alcohol. To produce a good soap, we must take the alkali in its pure or caustic state. Common alkali will not do. The usefulness of soap, and its importance as a manufacture, are very well known. It derives its solubility in water, with its detergent and penetrating qualities, from the caustic alkali which it contains. Nothing is so detergent and penetrating as the caustic alkali by itself. But the oil is necessary in the composition, in order to moderate the sharpness and activity of the alkali, and to give a slipperiness to the clothes to which the soap is applied. Were the alkali used alone, the clothes could neither be handled with safety in washing them, nor bear the hard rubbing and other mechanical violence necessary to extricate the matter which renders them foul.

The general process for the preparation of soap is to boil the oils or animal fats with a ley made of pure or caustic fixed

alkali. The boiling is continued till almost the whole of the water is dissipated. The vegetable alkali produces a softer soap, and the fossil a hard one. Soft soap can be changed into hard by boiling it with a solution of common salt. A double exchange takes place: and we have a muriat of potash and a hard soap. The process is a little delicate.

If we decompose the soap, and separate the oil from the alkali, we find that the oil will now dissolve in alcohol by itself. It has undergone some change in this respect which we do not understand. We have an easy way of thus separating the oil of soap for such experiments, by adding an acid to it. The cohesion of the oil and alkali in soap is easily overcome by acids, which, uniting with the alkali, immediately detach the oil.

From this effect of acids upon soap has been deduced the cause of what is called *hardness* in waters. Waters are called hard, when they decompose a little of the soap, and the oil comes to the top in a curdy form. We are told that such waters as do not dissolve soap are found to contain an acid, combined with some substance, which does not adhere to it so strongly as to hinder it from acting upon the alkali of the soap. Neutral salts do not render water hard. Macquer was led into the mistake that they did, by finding sea water generally in this state. But this is owing to Epsom salt contained in it. This salt, gypsum, alum, or metallic salts, always produce this effect. The addition of an alkali cures hardness in waters. This is too expensive when water is to be used in large quantity, as in bleaching, and other manufactures. In such cases, the choice of a good water is of immense consequence. Many chemical trials and tests are delivered by authors: but soap itself is the best of all.

The same hard waters are unfit for some operations in cookery, such as boiling vegetables soft. A little alkali may be of use here, and would improve the colour of the vegetables.

The effects of the mixture of acids with unctuous oils, are not so violent in general as with the aromatic oils. When the experiment is made with the sulphuric and nitric acids, a part of the acids is deoxygenated to a certain degree: but another part

unites with the oil, and forms a compound which has some solubility in water, and is named an *acid soap*. Strong nitric acid, however, mixes with the fat oils with violence and the extrication of great heat. Some of them, which are called drying oils, and are found to have a superior attraction for oxygen, are even set on fire, when the operation is judiciously managed, by pouring the second quantity of acid on the part that appears dry and charred.

Of the earths, the pure calcareous earth, or lime in its active state, shews a considerable disposition to unite with these oils. We have an useful example of this in mixing any of them with lime-water, which will mix with olive oil very intimately by a little agitation in a phial, and the compound is found to be a most excellent extemporaneous remedy for scalds and burns.

Of the other inflammable substances, sulphur is sometimes combined with some of these oils, for the purposes of medicine, forming the *BALSAMUM SULPHURIS CRASSUM*. It has a heavy hepatic smell. When the oil is very much saturated with sulphur, by means of a considerable heat, if the mixture be made to cool with extreme slowness, it deposits a great part of the sulphur in very beautiful transparent crystals of a dark ruddy brown colour. Sometimes the experiment appears not to have succeeded: and if we give the vessel a shake, it crystallizes in an instant, and so much heat is extricated that the mixture has sometimes taken fire.

So far as we have proceeded, the account I have given is applicable to the whole of these oils. But, in order to give more full information upon this subject, it is necessary to point out a few species, distinguished from the rest by peculiar qualities. These shew a little affinity with the aromatic, by containing a volatile principle, the presence of which in them is necessary to their fluidity, and which preserves them fluid in violent colds. It does not, however, give them an acrid and stimulating quality; for when they are quite fresh and uncorrupted, they are very mild: but it gives to some of them a perceptible odour. And, while it evaporates, in consequence of their being exposed to the air and to light, the oil becomes thick, and at last solid; for which reason, such oils are employed with paints, or

as varnishes. This change is found to be accompanied with a copious absorption of oxygen from the atmosphere.

The oils that come under this description, are those of lint-seed, hemp-seed, poppy-seed, and walnut-oil. On account of their drying up, and thus leaving a varnish on the surface of wood or other things to which they are applied, they are called **DRYING OILS**. Other unctuous oils never dry, but remain greasy, until they evaporate by decomposition, or are absorbed by dust, or other impurities. The drying oils also unite with acids a little more violently, and more like the aromatic oils than the other unctuous oils do.

Spermaceti and bees wax also belong to the section of unctuous oils, but differ in some particulars from the general description.

SPERMACETI is an animal fat, obtained from a particular species of whale, and differs from other fats, chiefly by having much more solidity and dry consistency in ordinary heats of the air. Hence it does not stain cloths, but rubs off; and in congealing, after being melted, it always displays a foliated texture. Dr. Crell made a very perfect soap with it. It burns with a brighter flame than the greater part of animal fats.

BEES WAX also differs from the unctuous oils, chiefly by having a greater degree of solidity in the ordinary heats of the air than most of them; by becoming ductile and plastic with a gentle heat before it melts; by giving a brighter flame; and by its origin. It is well known to be formed and used by the common honey bee in constructing its combs; and has generally been supposed to be formed by the insect from the staminal dust of plants, which they are known to gather and carry to their hives. But Mr. John Hunter lately found reason to assign a different origin to it. He thinks that it is a sebaceous excretion from their bodies, and comes out from under the scaly rings which cover their hinder parts; and that by the motion of those rings on one another, it is formed into the very thin plates with which they make up their cells, and incrust the inside of their hive, and any extraneous body in it which might give them offence, as a snail, &c.

Among the effects which these oils shew in mixtures, we must not omit to mention some consequences which attend mixing

them with one another ; as some of them in such mixtures produce effects which demand the greatest attention. There are some of them which, soon after they are mixed begin to act chemically on one another. The mass becomes first warm, then hot, and at last takes fire ; and, in some examples which happened in Russia, has set fire to ships of war, or to magazines of naval stores.

Four pounds of suet, rather greasy than firm, and half that quantity of lintseed, hempseed, or other drying oil, being mixed together, after a few hours become warm : and if this generated heat be prevented from escaping, by wrapping up the mixture in flannels, it increases to inflammation. The same effects follow when these oils are worked up into paints, with ochre and other colours : and when cloths, fresh smeared with them, are loosely rolled up in bundles, they grow hot, and scorch, and are thus consumed to ashes : and they frequently burst into flame.

This propensity to take fire seems owing to a stronger attraction of the ingredients for oxygen when in their compounded state. Of this we have many instances, such as sulphur, phosphorus, and mixtures of metals. The *black wad*, from Derbyshire, was sold for a black pigment, till it was found that cloths painted with it, ground with oil, could scarcely be laid up in the magazines without the risk of taking fire spontaneously.

The origin and uses of these oils deserve our attention, as they are subjects of an extensive commerce. Though the aromatic oils are more precious, these are incomparably more valuable and useful : but they are afforded by nature in far greater quantity, and therefore not so highly prized.

In many of the warm climates, the olive affords an excellent and very perfect unctuous oil in great quantity. In Africa, the negroes extract from the kernel of a palm an oil of this description,....the *oleum palmæ*. An excellent oil, which keeps very well, may be obtained from the *arachis hypogaios Americanus* of Ray. The pistil and germen of this plant point downwards, and penetrate the ground, under which the germen ripens to a sort of nut, or husky seed, called *ground pease*. It is much used for fattening fowls and swine. A bushel of this seed costs about eighteen pence, and will yield a gallon of oil of delicate

taste, and which keeps very well. (*Phil. Trans. vol. 59.*)* Through the whole extent of Europe, and in many other parts of the world, the subjects from which we get these oils are the animals which are slaughtered for our food, and the seeds of some plants, rape-seed, lint-seed, hemp-seed, beech-mast, and walnuts,...and also milk, the butter of which contains an oil of this kind as its principal ingredient. But besides, expensive voyages are made to the polar regions, to kill whales of different kinds, for a plentiful supply of the oil they afford. The inhabitants of countries nearer the pole obtain their oil entirely from different marine animals.

The uses, to which these oils are applied, are numerous and important.

1mo, They make up a part of the food of mankind in every part of the world in which they can be procured.

2do, They serve by their inflammation to give us light. And the Laplanders and Esquimaux use their fish oil, not only as their best cordial and most luxurious food, but depend on it for both light and heat in their subterraneous dwellings during their long winter nights.

3tio, Soaps, which are among the most useful productions of the chemical arts, cannot be made without these oils.

4to, They are also highly useful and much employed in all machinery, to diminish friction.

5to, And lastly, some of them are useful as paints or varnishes.

* The oil expressed from the seeds of hemp, which has been carefully reared for this purpose, and cleared from all bad stalks, is, when fresh, almost equal to the finest butter in sweetness. The offensive odour of hemp oil is partly owing to the husk, and partly to a natural change which this oil and some others undergo. The Russians, who are very nice, choose for this purpose the seeds before they are grown hard and dry, and do not allow either the plant or the seed to lie in a heap. The oil, when expressed, is not perfectly fluid and transparent, but rather like honey beginning to grain. They put it into small bladders, and keep it hanging in running water. I have eaten it three months old, and thought it preferable to their best butter...EDITOR.

EMPYREUMATIC OILS.

As Newman, Lewis, and others, have treated of these oils separately from the others, I have thought proper to follow the example. This term is applied to all oils which have been forced to rise in vapour, and pass over in common distillation, with a heat greater than that of boiling water, or which are produced by such a heat from substances which were not oily before. When oily substances, capable of bearing a heat higher than that of boiling water, are exposed to it, and made to assume the form of vapour, and distilled, they always undergo a change from their natural state. Oils, which naturally are quite bland, insipid, and destitute of odour, become acrid and stimulating, and strongly fœtid, and disagreeable.

Empyreumatic oils may be distinguished into four kinds :

1. Those produced from balsams or resins.
2. Those produced from unctuous oils.
3. Those produced from vegetable substances that are not of an oily nature.
4. Those produced by heat from animal substances not of an oily nature.

The first kind have, with the empyreumatic fœtor, an odour of the aromatic oil, which the balsam or resin contained. The second have the smell of the smoke of a candle or lamp when blown out. The third smell of wood burning. The fourth of burning feathers, horn, hair, bones, and other such animal substances.

When these oils are first distilled, they are dark coloured, and even dirty, by reason of charry matter which comes over with the oil. But this oil being put into the retort, will rise with a less heat, and come over more volatile and attenuated, leaving a carbonaceous residuum. This operation, repeated several times, brings the oil to a greater degree of purity, and, which is important, of uniformity or sameness, in so much that it is highly probable that by repeated distillations all distinctions will be removed. Bees wax yields an oil which approaches the most rapidly to this state : and indeed, after two distillations, it can scarcely be distinguished from an empyreumatical oil of olives that has been eight times distilled.

It may appear surprising to those to whom it is new, that such hard and dry substances as the hardest and driest wood, and the bones, horns, and other parts of animals, that have not the least of an oily nature, should afford empyreumatic oils by distillation with a proper heat. The fact, however, is easily explained by the discoveries and new principles of the modern chemistry.

I lately remarked, that all oils, in general, are principally composed of hydrogen and carbon, with a small quantity of oxygen, and perhaps of azote, together with a very small portion of earth.

Now these principles, which have thus been discovered to constitute the oils in general, are contained in all the animal and vegetable substances, as will be explained to you more fully hereafter, not excepting the dryest and hardest of these. When such substances, therefore, are exposed to the moderate action of destructive heat in close vessels, a part of the hydrogen, which is always a volatile substance, is volatilized, without being combined with that large quantity of caloric, which is necessary for converting it into inflammable air. It carries up with it a part of the carbon: and being condensed by cold in the receiver, it must necessarily be condensed into an oil, which is black, in consequence of the carbon it contains, perhaps imperfectly combined with it: and has a penetrating disagreeable smell, in consequence of the imperfect union of the hydrogen with the carbon and other principles which it contains. If there be azote in the composition of the matter, which is the case with all the animal substances, and even some of the vegetable, this principle, combining with some of the hydrogen, forms some volatile alkali: and if there be much of the oxygen, which is the case with all the vegetable substances, it contributes to form a quantity of carbonic acid gas, and very often an acid now called *pyro-lignic* (*pyro-xylic*), which is nearest by its nature to the acetous acid.

The same view of the nature of oils in general will also enable you to understand why dark-coloured, acrid, and fœtid, empyreumatic oils are produced by subjecting to heat for distillation the mildest and most bland of the natural oils. The mildness and sweetness and unctuousity of these depend

on the proper union and cohesion and proportion of their principles ; all of which conditions are altered by the action of heat.

The empyreumatic oils agree with the aromatic in several particulars. A small quantity of them can be combined with water, or dissolved by it. They are dissolvable by alcohol : and they have not the lubricating quality of the unctuous oils.

All of them contain a very fluid and volatile oil, mixed with a grosser one. And the tenuity, volatility, and inflammability of the more volatile part of them, is in some cases very remarkable. Oil of wax is one of these.

One is valued in medicine, but not much used....OLEUM ANIMALE, or OLEUM CORNU CERVI RECTIFICATUM. (*Ph. rm. Edin.*) Another, called *the oil of bricks*, because it is distilled from a red hot brick which has been thrown into olive oil and impregnated with it, is used by the seal-cutters and lapidaries, for moistening the diamond powder with which they work, that it may adhere to their tools.

The principal example we have of the application of oils of this division to useful purposes, is in the use of tar and pitch. TAR is the first production. It is procured from all the trees of the pine kind, by a rude kind of distillation. In Germany, Norway, and Sweden, where this timber is very abundant, it is piled up in billets, in a sort of oven, which is covered with another oven, at a very small distance. The fuel is put into the interval between them. Thus the inner oven becomes a sort of retort, and the oily vapours having no other outlet, run from a gutter made in the floor of the oven. This exudation contains much soot intimately mixed; which makes the tar quite black. PITCH is made of tar, by separating the more volatile and fluid parts by evaporation or distillation. The tar is an empyreumatic oil extracted by heat, and contains a portion of the essential oil of turpentine, which is in all firs, and a quantity of the acid called now *pyrolignic*. Hence tar-water, while it has that irritating acrimony common to all the empyreumatic oils, is manifestly acid, and affects the vegetables purples.

VII...BITUMENS.

THE seventh section of the inflammable substances contains BITUMENS. Under this title I comprehend all the fossil inflammables, except sulphur, already described.

Some of these are fluid, and some are solid. The most subtle of them is certainly that species of inflammable air which often occurs in coal-mines and other subterraneous places, and which I had an opportunity to mention formerly, as liable to take fire from the flame of a candle, and to make dangerous explosions. It must be considered as an inflammable substance of such great volatility, that under no greater pressure than that of the atmosphere, the ordinary temperature of heat is much more than sufficient to preserve it constantly in the form of vapour. The hydrogen gas is surely its most abundant ingredient. I do not know that any person has made experiments with this kind of air, to investigate the nature of it very particularly. But I have no doubt that it is heavy inflammable air, or that variety which contains carbon dissolved in it*.

Next to this vapour, we may reckon the fossil oil called NAPHTHA, and the varieties of it, called PETROLEA. The naphtha is described as a fluid of a very light yellow colour, or sometimes colourless; and which has a degree of fluidity and tenuity equal in appearance to that of alcohol or æther: but it is oily, and floats on water like æther. It is also very volatile, and highly inflammable, catching fire at the approach of flame rather more readily than alcohol. The flame of it, when not very small, is attended with some smoke or soot, as that of all other oils. The odour of it is strong and oppressive to most persons. Such a fluid is said to be gathered from the surface of the water of certain wells in Persia, and in the dutchy of Modena in Italy. But it is a rare production of nature.

* What escapes from the crevices of the Whitehaven coal-mines gives no indication of any carbon. The air in which it burns for a very long while does not affect lime-water. . . . EDITOR.

The fossil oils, called petrolea, are not so rare; but are inferior to naphtha in fluidity and volatility, though some are still very fluid and volatile. The different varieties have different shades of a yellow or brown colour, and a heavy, oppressive, penetrating odour; and are highly inflammable. Such are found in several places in Italy, Sicily, Bavaria, and France, issuing from the crevices of rocks, or floating on the waters of springs or wells; and readily take fire by the contact of flame, and burn on the surface of cold water.

The fossil inflammable substances which are next inferior to these in fluidity, are those to which the name of bitumen has been most particularly applied. Such are a number of species which have a consistency resembling that of tar or pitch, or that of the vegetable balsams. They are distinguished, according to their different degrees of fluidity or consistency, by the names of *pissoleum*, *pix judaica*, and *pissasphaltum*. Some are little darker in their colour, or thicker in their consistency than the coarser petrolea; while the thickest, or most gross, the *pissasphaltum*, is actually solid when cold, and requires heat to give it fluidity, in the same manner as pitch. When cutting a level to a coal mine on the bank of the Severn, near the iron bridge, a source of this kind was discovered in a stratum of free-stone. It yielded this tar in considerable abundance at first; but this gradually abated,...and after two years seemed to be exhausted. It had accumulated in the pores of the sand-stone through a length of time, and had now drained off. A similar case occurred in Renfrewshire a few years ago. St. Catharine's well at Liberton has yielded this substance for more than a century, and does not seem to abate. But the quantity is not great.

The very fluid bitumens are in general such rare productions of nature, especially the more subtile and volatile kinds of them, that they have been but little examined by the chemists. They have much of the appearance and properties of the empyreumatic oils.

The solid bitumens are AMBER and COAL. The common appearance of amber is too well known, to need description. There are also varieties of it. The most valued pieces are of a light yellow colour, and either transparent, or agreeably clouded

with white. But it is much more frequently found of a deeper yellow or brown, or even almost black and opaque. Amber is distinguished by an aromatic odour, which it emits when rubbed. This, and some other particulars, give it a great resemblance to some vegetable resins. But it differs from all that are known in some of its properties.

If it be heated gradually, and the vapours condensed in close vessels, it gives first a small quantity of water. This is followed by a salt, part of which is dissolved in the water, and part condensed into a solid form. Along with this salt, and after it passes over a large quantity of empyreumatic oil, and some inflammable gas. Little charcoal remains. This salt is an acid, strongly tainted with the empyreumatic oil, more resembling the vegetable acids than any other. The oil has an exact resemblance to some petrolea; and, if repeatedly distilled, becomes so like naphtha in every property, that they cannot be distinguished.

The natural history of amber, as found on the coasts of the Baltic, is given by Hoffmann and Newman; to which may now be added, that it has been found of late years abounding in Royal Prussia, near the shores of the Baltic, by digging pits of considerable depth, till they reach a stratum of forest trees, bedded in sand, or at least under a stratum of sand. The trees are all charred, and perfectly black. The amber is found among them in nests, and the working of these mines is found very profitable. The floating amber is, in all probability, torn up from the bottom, where the sea has penetrated to this stratum. (*Crell's Annals of Chem.*) It is found in general in small bits. Pieces that are four, or five, or six inches in diameter, are exceedingly rare; and if they happen at the same time to have beauty, are very highly valued. It has, therefore, been a desideratum among the chemists to unite small bits of amber into larger masses; and some have been reputed to possess such a secret. But it does not appear that it has ever been practised, or that it is possible.

PIT-COAL, the other solid bitumen, is of much greater value to the countries which possess it, in which it is well known to constitute thick, numerous, and extensive strata. And though

inattentive observers consider it all as the same, we find remarkable varieties of it in the different strata which it forms. I shall here mention the most distinguished varieties only. There are many others intermediate between these; but we need not attend to them all.

1. *Cannel coal*, or *candle coal*; or, as it is named by our colliers, *parrot coal*.

2. Common *Scotch coal*, in which our colliers distinguish some varieties; but we need not enumerate them.

3. *Fat*, or *caking*, or *blacksmith's coal*,...*smithy coal*.

4. *Kilkenny coal*; or, as our miners call it, *blind coal*.

These different kinds of coal are distinguished by their manner of burning, and by the products they afford, or phenomena they exhibit, when they are subjected to the operation called chemical analysis.

The first kind, or candle coal, kindles easily, and gives in burning an extraordinary blaze of bright white flame.

The second, which is the most common in this country, also gives in burning a good deal of white flame, though not so much as the first; and the cinder or charcoal that remains, when it ceases to flame, is a better fuel, or contains more of the carbonaceous principle than the cinder or charcoal of the candle coal.

The third kind, the fat, or blacksmith's coal, gives less flame in burning than either of the two former: but in beginning to burn, or before it begins, it is in some measure melted by the heat; at least a bituminous matter that is softened and melted by the heat, oozes out of it, and occasions those bits that are in contact to cohere together. So that, when a quantity of it in small fragments, or perhaps partly in dust, is laid on a fire, and wetted with a little water, to make the fragments and dust enter into closer contact, it very soon coheres together into one mass, which being afterwards broken or divided a little, to let the air pass through it, burns strongly and a long while, giving a great deal of heat before it be totally consumed. The cinder or charcoal of this kind of coal is very rich in the quantity of its carbonaceous principle.

This kind of coal is but rare in this country [Scotland]; but in some of the principal coal counties of England, Newcastle and Whitehaven, it is the most abundant. It is the most valuable of any, on account of its not suffering waste by being broken down small; for in the smallest fragments, it is equally good for household purposes as the large pieces; whereas the greater part of the Scotch coal, when broken down to dust and small fragments, becomes quite unfit for household purposes. By running like sand into all the interstices through which the air should pass, it extinguishes a fire instead of mending it. In this state, therefore, it is not called coal, but *culm*; and is only employed for burning brick and lime, and for making salt from Sea-water. The English fat coal, though ever so small, is never called culm; for this reason, that by its caking quality, it makes excellent household fires, and gives a great quantity of heat before it be totally consumed. It is also the most thrifty; as it does not burn much when the fire is left at rest.

This kind of caking coal, when it is free from any admixture of sulphur or pyrites, is also highly valued by the blacksmiths, and is even necessary in some measure to their operations. It enables them to make what they call a *hollow fire*. When they have occasion to heat a mass of iron, or a thick bar, they put it into their fire, and cover it with a large round heap of this sort of coal, wetted on the outside, and then by working their bellows for some time, and other management, the coals that were in immediate contact with the iron are consumed, and a hollow is formed around it like an arch or little cavern, the sides of which are all composed of coal caked together. While the wind of the bellows is driven into this cavity, and circulates in it, a violent heat is produced all around the mass of the iron; and every part of its surface receives the necessary degree of it, which could not easily be obtained by using other coal that is unfit for forming the hollow fire. Such are the properties of the third kind of coal, the fat or caking coal, or smith's coal.

The fourth and last kind of coal I mentioned, the Kilkenny coal, or, as it is called by our colliers, the *blind coal*, differs greatly from the others by its manner of burning. It is more difficultly kindled; and when perfect of its kind, gives no flame

whatever, but burns exactly like charcoal, and gives a great deal of heat before it is consumed. As it neither gives flame nor smoke, it is burnt in malt-kilns for drying the malt, the air which comes from it in burning being quite free from fuliginous vapours. It appears probable, therefore, that the volatile parts of this kind of coal have been separated or expelled from it by some operation of nature.

Such are the differences of these four kinds of coal in their manner of burning. They differ also, as I said, by the products they afford when they are subjected to distillation performed without addition, in retorts and receivers.

I shall first describe the effects of this operation when performed with the most common coal of this country, the common Scotch coal.

If the receiver be closely luted to the retort, and kept very cool, and provided with an air-pipe, we obtain, *first*, a small quantity of water, little different from pure water.

Secondly, While the distillation advances, and the heat is increased, more water comes over, attended with a brown oil.

Thirdly, The heat still increasing, less of the water comes over, but much more of the oil; and at last scarce any thing but black oil is seen to condense in the receiver.

The oil that comes at first is thin or very fluid, and of a brown colour. That which comes afterwards is thicker and darker coloured: and at last it condenses quite black, and as thick as tar. It continues to come in the form of a thick smoke, to the end of the operation, that is, until the retort is heated to a degree of ignition, by which the remaining matter is changed into charcoal, and no more volatile matters can be expelled from it by an increase of heat.

Fourthly, During all the time, when the oil is distilling, especially after the first of it has been condensed an immense quantity of elastic aerial matter passes out through the air-pipe, and may be collected in inverted vessels. A part of it is carbonic acid gas, which precipitates lime from lime-water. But the greater part is hydrogen gas, or inflammable air, not of the purest and lightest kind, but containing a quantity of the carbon, or carbonaceous principle, intimately combined with it. And

~~Distilled water~~

therefore, when a mixture of it and oxygen gas or vital air are fired together, the consequence is not the production of water alone, but of water and of a quantity of carbonic acid.

The whole of the oil is of the empyreumatic kind, not unlike to tar in colour and consistence, only more fluid: and it has a very offensive smell, similar to that of the smoke of coal fires when they are beginning to burn. Like other empyreumatic oils, it is partly composed of a very volatile and fluid part, and a grosser one. They can be separated by distillation with a gentle heat, by which we obtain a portion of the oil very fluid, and volatile, and transparent, and of a yellow colour, very much resembling some of the petrolea. What remains in the distilling vessel becomes more like tar or pitch in its consistence and properties; and is now manufactured, in order to be employed as tar,...the more volatile oil being at the same time prepared for making a sort of varnish.

Along with these oils, I said that a quantity of water is always extracted from the coal by the same operation. And this water contains some volatile alkali, which at first is intimately combined with some of the oil, but is separated from it by rectification, &c. and afterwards can be employed in the manufacture of sal ammoniac.

These are the products which we obtain by distillation from the common Scotch coal. But there is some variation when we perform the same operation with the other kinds of coal I enumerated.

The candle coal yields much more of empyreumatic oil and other volatile products than the other kinds.

The common Scotch coal is the next to it with respect to the quantity of empyreumatic oil, or volatile inflammable matter, which it affords.

The fat or caking coal affords still less oil, but a very rich charcoal.

And the Kilkenny, or blind coal, affords none at all, and scarcely any volatile matter whatever. It may be considered as a natural charcoal.

Such are the principal varieties of bituminous inflammable substances found in the earth. And when we study their natu-

ral history, and some other particulars relating to them, we find great reason to be persuaded that all have derived their origin from vegetable matter.

In pit-coal many appearances occur which lead us to such a conclusion with regard to this sort of bitumen. It is common to observe impressions of leaves and other parts of vegetables in the strata, which lie above or below the coal. And very frequently in the coal itself we find a black matter, which has so much of the structure of wood, and so exactly resembles bits of wood which have been scorched or burnt to a sort of charcoal, that there is no room to doubt of its origin. This matter frequently occurs in the coal which we burn here, and always forms a sort of thin strata intermixed with those coals, and composing part of it, and occasioning it to split easily, in the direction parallel to the two surfaces of the stratum.

Sometimes little masses of the coal are entirely made up of this sort of matter. I have been informed that some of the coals of England contain a remarkable quantity of it, and are distinguished by the name of *clod-coal*, and valued as the best for melting iron from its ore. And the same matter appears in a bit of coal which was brought me from the coast of Greenland.*

From these and other facts and appearances, it has been concluded that pit-coal has been formed of vegetable matter, carried into the sea by rivers; and which having sunk to the bottom in consequence of its being thoroughly soaked, has there undergone a degree of decomposition, and has been strongly compressed by other materials deposited over it, and in some cases has

* In 1759, coals were brought on board the Royal William, in Louisburg harbour, which had been bought for the captain's firing. When his steward saw them, he refused to take them, saying that they were only charred wood. The vegetable structure was very distinguishable in the greatest part of them. One piece in particular had unquestionably been a large root of the common marsh iris. Its joints, and the commencement of the air vessels at the big end, could not be mistaken. Some pieces being first made red hot under sand in a pipkin, so as to dissipate a heavy stinking smoke, burnt afterwards with a smell perfectly resembling that of wood charcoal. This coal had been brought in the boat from the mouth of the mine, in the face of a cliff, from which they had been let down by a pulley into the boat....EDITOR.

been penetrated with mineral vapours and subterranean heat, so as to give it the various qualities and appearances we see in coal.

The other facts, besides the appearances already mentioned, which have suggested such an opinion are these :

1st, Great rivers, in different parts of the globe, are well known to carry annually vegetable matter into the sea, especially those which have a long course through immense uncultivated tracks of the earth's surface that are overgrown with wood, as some of the great rivers of North and South America, Africa, India, and the Russian territories. Great rivers necessarily have a great part of their course through level countries, through which they make many serpentine turns. And they are constantly undermining their banks in some of those turns, and occasioning wood, leaves, moss, and other vegetable matters, to fall into their stream. Some of this matter floats for a long time, until it be so thoroughly soaked as to sink to the bottom. But while it floats, it is carried down to the sea, and perhaps afterwards to a very great distance, by tides and currents. Sometimes it runs aground in the shallows that are at the mouths of such rivers, and gradually forms islands in those shallows, as at the mouth of the Mississippi. But the greater part is carried out to sea. Great quantities of timber are found floating in the northern seas, on the coast of Iceland and Greenland, and the north coast of Russia. All this, after floating some time, must sink to the bottom. In Iceland there is a large bay which is always full of floating wood, and supplies the inhabitants with fuel.

2dly, The very circumstance of coals being formed into strata is strong in favour of this opinion; as we have the greatest reason to be satisfied that all strata have been formed of matter carried into the sea. But, besides, we find these strata of coal always intermixed with other strata, which have been manifestly formed in the sea, as sandstone, limestone, and clays of various kinds.

3dly, In some parts of the world, among strata of the same kind with those which commonly accompany coal, are found strata manifestly composed of wood, even trees com-

pressed and compacted together, so as to form strata, bearing some resemblance to those of coal, but in which the wood retains so much of its original structure and shape that it cannot be mistaken. There is an example in Devonshire, called *Boveycoal*; and a stratum of fossil wood in the north of Ireland.

All these reasons, therefore, leave little room to doubt of the origin of pit-coal in general, although in many varieties of this bitumen, the first contexture of the materials has been so much abolished by immense compression, and the penetrating and dissolving powers of water and heat, and other causes, that we hardly find any remains of it. It is probable, too, that many strata of coal have been formed of other vegetable matter, as moss or peat,....carried into the sea during a long course of time, by rivers which have their course through extensive tracks of the earth's surface, abounding with bogs and moors.

When we study the varieties of the other solid bitumen,amber, we can clearly trace its origin also from vegetable matter. It is not at all uncommon to find in amber, insects of various kinds, either such as creep on the trunks of trees, as ants, spiders, caterpillars, or flying insects that frequently alight upon trees, or live upon them: such are a variety of flies and moths. In the British Museum there is a lizard in amber; a reptile which is well known to creep on the trunks of trees, or to dwell about their roots. Further, these things are immersed in the amber, and every way surrounded with it; and, from other appearances about them, it is plain that the amber must have been soft and viscid, like the vegetable balsams, when they adhered to it, and when it involved them.

This, and the chemical qualities of amber, by which it resembles greatly the vegetable, balsamic, and resinous substances, gives sufficient proof that it was once one of these. It is well known that many forest trees, in different parts of the world, at certain times of the year, shed from ruptured parts of their bark, large quantities of balsams or turpentine, a part of which must fall into rivers; or, if deposited in the soil, must be washed out by them afterwards some time or other, while they gradually change their channel by undermin-

ing their banks. This matter must be rolled along by the river until it reaches the sea, or is left behind, in some part of the bottom where the water has little motion, and by length of time, and the action of mineral vapours, assumes the qualities which we find in amber.

Such, therefore, appears to be the origin of the solid bitumens, coal and amber. That of the fluid may perhaps be thought more difficult to trace. But I think we have clear lights for this part of our subject also. We must, in the first place, consider that the fluid bitumens bear a surprising resemblance to the empyreumatic oils which may be extracted or produced by fire from the solid. Some specimens of the petroleum resemble exactly the empyreumatic oil of amber. Others resemble the oils which may be extracted by fire from different kinds of pit-coal or fossil-wood. And all the fluid bitumens resemble these oils more or less. We must also reflect on the evident signs of subterranean fires which are frequent in different parts of the globe, particularly the hot springs; many of which pour forth amazing quantities of hot water, and thereby shew that the fires by which their heat is maintained have great power and permanency. This is further proved by the eruptions and steams of volcanoes, which are very numerous over the face of the globe; the fires of which must be at an immense depth below the surface, and must have very extensive communications, as is plain from the extensive effects of earthquakes, which manifestly depend on these subterranean fires. If to this we add what we observed in some kinds of pit-coal, which shew by their properties that the volatile parts have been expelled, it will be easy to gather from all this some highly probable conjectures concerning the origin of the fluid bitumens. We can hardly avoid being persuaded that they have been produced by the long-continued action of subterranean heat on the materials of the solid bitumens, the volatilizable parts of which are gradually separated from the rest by a sort of natural distillation or chemical analysis, and are driven upwards through the crevices or pores of the earth, until they come near to the surface, where they escape from the further action of the subterranean heat, and are within our reach.

In confirmation of this supposition, it may further be remarked, that some of the countries in which those oils are found the most frequent, are well known to be undermined by subterranean fires, especially Italy.

And not only the fluid bitumens, to which this name is commonly applied, but that more subtile substance, the inflammable air, or fire-damp, which occurs in mines, or breaks out at the surface of the earth in some places, may be imagined to have the same origin. When we expose the solid bitumens to the action of heat in close vessels, besides the empyreumatic oils which we obtain, and which resemble the fluid bitumens; we obtain also great quantities of inflammable air, or inflammable gas, which must necessarily be produced from solid bitumens or fossil wood, on many occasions by subterranean fires:

Thus, therefore, the whole of the subterranean inflammable matter, that belongs to the title of bitumens, may be imagined to derive its origin from vegetables. From whence the vegetables again derive theirs, will perhaps appear when we come to consider the matter of vegetables, and its production, as a particular subject of chemical inquiry. (*See Note 49. at the end of the Volume.*)

CLASS IV.

METALLIC SUBSTANCES.

THE metallic substances are now to be considered as the Fourth Class of the objects of Chemistry.

They probably attracted the attention of mankind at first by their shining surface. But when their nature and properties became better known, they were valued as materials with which we can easily execute many purposes in arts which cannot be attained without them.

The qualities which render them useful and valuable are,
1mo, Their fusibility and malleability, by which we are enabled to melt different masses of them into one, or easily to divide large ones into small ones, and to mould or hammer, or otherwise work them into the forms which our purposes require.

2do, The strong cohesion of their parts, in consequence of which they are the proper materials for all parts of machinery, or other works in which great strength or long duration is required.

3tio, The different degrees of hardness and elasticity which some of them can be made to assume, render them highly useful to us on innumerable occasions, for the fabrication of tools, springs, and many other implements necessary in the arts.

4to, The density of their substance, which is impenetrable to water, and most other kinds of matter, is one more of their useful qualities. And,

5to, and lastly, Their bearing sudden alterations of heat, without being broken, is another.

These several qualities render them useful for many different purposes. And further, by their lustre and brightness, and the facility with which they are polished and wrought into ornamental forms, they are fit subjects for many of the elegant arts.

The metallic substances are, for these and other reasons, much more the objects of attention and study than the other classes of natural bodies.

And yet we have gained less advantage from the researches of many of the chemists on this subject, than what might have been expected, from the great labour which has been bestowed on it. The reason is plain. The greatest number of experiments formerly made upon metals were prompted by the visionary projects and notions of the alchemists. Instead of directing their investigations to the discovery of new productions that might be useful in life, their sole aim was to convert cheaper metals into gold and silver. And it happened at the same time, that the greatest number of those who were employed in this pursuit, were persons of so little education, and so ignorant, not only of other sciences, but even of any rational principles of chemistry itself, or of the nature of the materials which they employed, that they were for the most part incapable of making experiments in a judicious manner, or of understanding them properly when they had made them. Their extraordinary labours must no doubt have led them to the knowledge of many curious facts. But every experiment which deserved attention, was coucealed by them with the greatest care : or if they mentioned, or pretended to describe any discovery, they did it in such mysterious and ambiguous language, as must render the study of it insupportable to those that ever read any thing else ; besides that they every where abound with absolute falsehoods.

I shall not, therefore, attempt the disagreeable and fruitless toil of inquiring into the meaning of their opinions and processes ; but confine myself to such an account of the metals as may be deduced from clear and simple experiments.

Upon this plan, I shall first mention the more general qualities of the metals, and afterwards describe the nature of each in a more particular manner.

1st, The most obvious general quality of the metals is their great weight or density, in which they exceed all other known matter. The heaviest stones are not more than four times as heavy as water, or scarcely so much. The lightest of the metals is seven times heavier.

2dly, They are remarkable also for a great degree of opacity, and a power of reflecting the light strongly from their surface ; in consequence of which all mirrors are made of metallic substances, or are made to reflect light by their means. The thinnest leaves or films of metal have this power to a surprising degree : but we can in some cases reduce them to films of such exceeding thinness, that they transmit a very small part of the light which falls upon them.

3dly, Metals are distinguished from all other solid bodies by some qualities with regard to electricity, which give them the first rank among *conductors* of electricity, and which subject them on all occasions to be more affected by lightning than any other sort of matter which comes in its way. By *conductors* electricians mean bodies which are disposed to receive readily and quickly the electrical fluid, and to transmit it in a moment through their whole substance and surface ; so that when we communicate a charge of electricity to any one part of them, it is communicated to every other part of them at the same instant of time ; or if we abstract electrical matter from any one part of them, every part of them will be found to be equally affected by the abstraction. *Non-conductors* are the opposite to this. They receive difficultly, and transmit very slowly. For this reason they are employed in electrical experiments for *insulating* bodies,....and also for collecting the electrical fluid when we desire to accumulate it or make it act on different bodies. The electrical fluid is collected in general by rubbing a smooth polished surface of these non-conducting bodies.

All other kinds of solid matter, provided they are made perfectly dry, have more or less of the *non-conducting* and *insulating* power. But the metals have none of it. The electrical fluid, when accumulated in any other bodies, has always a disposition to pass from these to the metals, and to be diffused from one part of them to another, with such

astonishing velocity, that it can be conveyed by a wire to the greatest distance without requiring any perceptible time for its passage. Mr. Cavendish found by experiments, that iron conducts the electrical fluid 400,000,000 times better than water; that is, a current of this fluid will pass as readily through 400,000,000 inches of iron wire as through one inch of a cylinder of water equal in diameter to the wire.

4thly, Another quality of the metals in general is observed in their manner of assuming a fluid form by heat. They retain their opacity in their melted state, and form a fluid which has a bright and reflecting surface, and which is repelled by most other kinds of matter, or which does not adhere to them, and spread itself on them, as water and many other fluids do. Small drops of melted metal, therefore, form themselves into little spheres, in consequence of the stronger attraction of their particles for one another than for the surrounding matter. This happens not only when the small drops of melted metals lie on the surface of various solid bodies, but also when they are immersed in fluids, as water, oils, melted salts, and melted earths, none of which will mix with the metals, so long as these retain their metallic form.

These several qualities of the metals,...their excessive weight,...the opacity and reflecting brightness of their surface,...their being such perfect conductors of electricity,...and their mercurial manner of fusion, as it is called, form the distinction between them and other bodies, and are the only qualities which are found in them all without exception.

But we may also take notice here of malleability, laminability, and ductility, as among the general qualities of the metals; for, though these qualities are not found in all of them, the greater number have them, and metals are the only bodies in nature in which they are found in an equal degree. These qualities are distinct from one another, and do not always go together. Some metals have all the three in a high degree, *e. g.* copper, silver, gold, and platina, when pure. Others have two only, as tin and lead, which are malleable and laminable, but not ductile. Others, on the contrary, as iron, are ductile, but not malleable and laminable. Others, as zinc, are laminable, but not at all ductile, and scarcely malleable.

The most malleable metals, however, are liable to become rigid and hard by hammering, in consequence of the expulsion of latent heat: and they must be softened again by annealing, before we can proceed to hammer them further. I had occasion formerly to explain annealing, and how it is performed. Tin and lead are annealed in some degree by the heat of boiling water, and, by a somewhat stronger heat, are perfectly softened. Iron, copper, silver, and gold, must be made red hot. Platina is with great difficulty annealed.

Such, therefore, are the more obvious general qualities of the metals.

To take, in the next place, a more chemical view of them, let us attend to the effects of heat on the metals in general.

1st, Each of the metals is well known to require a particular degree of heat for its fusion; and some require very violent degrees. Dr. Boerhaave's opinion or suspicion, concerning the heat of some metals in their melted state, is perfectly groundless.

2dly, After a metal is melted, if we increase its heat to a much higher degree, most of them may thus be changed into vapour. And in close vessels, some of them can actually be distilled or sublimed; though in general the free access of air to such metals, when violently heated, makes them evaporate much more readily than they will do in close vessels.

But, in order to understand fully the action of the air on the metallic substances, when they are strongly heated, it is necessary to know that they greatly resemble the inflammable bodies, by having a remarkable disposition to attract oxygen, and to combine with it. And this combination, in some cases, is attended with the same phenomena of heat and light as in the case of bodies commonly called inflammable. For example, filings of zinc, or of iron, when thrown into a clear coal fire, burn with a distinct flame. This inflammability appears from many other facts and experiments; among others, from the effects of nitre, when it is applied very hot to the metals: there is a deflagration, as it is called, in the same manner as when that salt is made to act on the inflammable substances; with this difference only, that in the experiments with metals, it is necessary to apply a much stronger heat to bring on the action of the nitre and metal

on one another. Filings of zinc, when thrown into melted nitre, burn with a flame so brilliant and dazzling, that the eye cannot bear it. If the nitre be red hot, filings of iron will exhibit the same appearance; but it is not near so brilliant. Filings of a mixture of lead and tin come next to these two in inflammability and brilliancy. The metals are thus suddenly changed into an earthy-like matter, which is mixed with the remainder of the nitre. I call it an earthy-like matter, this being its general appearance. It is still, however, very different, according as the experiment is made with the different metals. But in none of them does it retain the appearance of any of the general qualities of metals which have been already described.

A further proof of the affinity of the metals to the inflammable substances, is, that they are liable to suffer a change by the joint action of heat and air, similar to that which the inflammable substances undergo, a change analogous to inflammation. This change, in the case of the metals, was called **CALCINATION**. A higher degree of heat is necessary to bring on this change in most of the metallic substances than that which is sufficient for the commencement and continuation of the inflammation in the bodies usually called combustible. And there is a certain latitude, or range of the scale of heat, which is best adapted to the calcination of the metals. In the lower degrees of this range, metals are calcined slowly and with difficulty. Near to the middle of it, the metals, in general, are the most quickly or perfectly calcined. In the higher degrees, the calcination does not go on so well. And when we increase heat to an intensity much above the range I now speak of, some of the metals exposed to such violent heats will retain their metallic form, though they may easily be calcined in inferior heats. The reason apparently is, that in very violent heats the air acquires too much elasticity, and is too much rarefied, to act on them with sufficient power: and the action of the air is fully as necessary to their calcination as the action of heat. If you would wish to know in what part of the general scale of heat this range fit for calcination is contained, I cannot be precise in pointing out its limits, as they are by no means distinct. I can only say that it appears to be comprehended within

what are called the red heats, which, however, have many differences of intensity. Below these red heats, and also in heats that are far above them, or what are called the white heats, calcination does not go on so well, at least with most of the metals.

The matter, into which the metals are changed by *calcination*, is also an earthy-like matter, similar to the matter into which they are changed by the action of nitre. The colour and other properties of it are different, according to the metal from which it is obtained, and partly too, according to the manner in which the calcination has been performed. This matter has been a long time called the *CALX* of the metal; and from it the operation by which it is obtained was called calcination. The term *calx* was chosen on account of a supposed analogy between the calcination of the metals and the burning of lime; though it is now well known that these two operations are of a totally different nature: and accordingly, the French chemists propose to set aside these terms of *calx* and calcination, as very improper, and to substitute others which I shall soon explain to you. In the mean time, we shall proceed to make a few more remarks on the calcination of metals in general.

In the first place, I wish you to understand, that metals, thus calcined, or changed into calces, are not always calcined to the utmost degree of which they are capable. By a certain moderate action of heat and air, they can be changed into calces, which may be further changed by a continued or more effectual action of the same powers. This gives occasion to a great diversity in the calces of some of the metals which are capable of these different degrees of calcination. A general account of which diversity may be given in this proposition, That the farther the calcination is pushed, the more does the *calx* resemble an earthy substance, or it is whiter, and the less disposed to fusion by itself; and on the contrary, the less they are calcined, they have the more colour, or they are less white, and retain more of their fusibility. Of this there are many examples, as in the calces of antimony, tin, and some others.

But the nature of the *calx* produced, and the phenomena and quickness of calcination, are very different in the different cases, partly in proportion as the heat is more or less strong, and more

especially, as the operation is performed with the different metals. You will easily perceive that there must be great variety in the calcination of the different metals, if you attend to these particulars :

1st. The different metals are more or less calcinable one than another. Some with great difficulty, and they are but imperfectly calcinable. Others are more calcinable, but still are calcined slowly, and with some difficulty. Others, again, are much more disposed for calcination, and, in proper circumstances, are calcined easily and quickly. While there are others which can be calcined to a certain degree only, but after this, resist the action of heat and air, without suffering much further change.

2d, If you also reflect on the great difference of the metallic substances in their fusibility and volatility; some being easily melted with a very moderate heat, while others require the most violent; and that some can also be easily converted into vapour, while others endure an intense heat a long time, without being volatilized by it;...you will perceive that the heats proper for their calcination must bear different relations to the heats necessary for their fusion, or conversion into vapour. Some, which require strong heats to melt them, are best calcined in degrees of heat inferior to those necessary to their fusion. Others, much more fusible, must be melted and heated much above their melting point, before they can be calcined. And of the volatile metals, some do not calcine fast, without applying to them so much heat as converts them into vapour.

Further, the calcination, in some cases, goes on so slowly or to such a moderate degree only, that it is not attended with emission of perceptible heat and light. But in other cases, there is a plain appearance of inflammation, the calcining metal being seen to glow like a burning coal; and in others, a bright flame is produced, like that of some volatile inflammable bodies.

What I have now said will give you some general knowledge of the phenomena which attend the calcination of metals in different cases and varieties of this operation. But you may form a more distinct notion of this variety by attending to some examples which I shall now relate :

1. Copper requires a strong heat to melt it; and therefore calcines best in a heat inferior to its melting heat. It is not capable of being calcined fast, or to a great degree: and no light or heat is observed to be produced by its calcination.

2. Tin is very fusible; and therefore melts before it calcines. But when a proper heat is applied to it, it calcines fast, and more perfectly than copper, and with appearances of combustion. The calx, when well calcined, is very refractory, or hard to melt.

3. Lead, like tin, is very fusible, and therefore melts before it calcines. When the calcination is performed with a strong heat, the metal smokes all the while, or emits vapours; and it appears inflamed, or emits more heat and light than the surrounding matter,...and its calx, being a very fusible one, flows around it in a melted state.

4. Antimony is very volatile; and therefore emits vapours plentifully in a calcining heat, which vapours are at the same time calcined, and the calcining metal emits light and heat.

5. Zinc is similar to the former, only more volatile, and in calcining, gives a dazzling light.

6. Lead and tin mixed. Mixing metals together increases their disposition to calcine. It increases their fusibility also; and therefore diminishes their cohesive attraction; which diminution of the cohesive attraction is probably a consequence of the chemical attraction of the two metals for one another; as chemical and cohesive attractions are generally antagonists to each other. But by the diminution of cohesion the chemical attraction of the metals for oxygen will be increased*.

As the matter, into which some of the inflammable substances are changed by inflammation, can be restored again to its former state; so the calces of metals can also be restored to their former state, and made to resume the metallic form. The

* I would just observe here, that Dr. Black, in his earliest lectures, ascribed much of the increase of weight which is observed in the calcination of metals, to the absorption of air, and its combination with the metallic substance. He observed that this increase is always small when the operation is performed in close vessels; and asserted that there would be none in vessels exhausted of air. I have before me notes taken at his lectures in Glasgow, in 1762, containing all these remarks.....EDITOR.

110 REDUCTION OF METALS...HOW EFFECTED.

operation by which this is effected is called **REDUCTION**, and is commonly performed by heating the metallic calx strongly, in contact with charcoal, or mixed with it. Thus the charcoal, or a part of it, is consumed, while the metallic matter recovers the metallic form. And to reduce a metallic calx in this manner, we can employ the charcoal of any inflammable substance from which a charcoal can be obtained, whether it be vegetable, animal, or fossil. There are even examples of metallic calces being reduced, by inflammable substances, under other forms than that of charcoal. Oils, and even alcohol, may be used. And nothing reduces the greater number of calcined metals better than hydrogen gas, when it is properly applied. This was first taught us by some of Dr. Priestley's experiments. He placed different metallic calces under glass receivers, or jars, filled with inflammable air, confined by water or mercury; and then applied to them the rays of the sun, collected into a focus by a burning-glass. The consequence was, the quick reduction of the metallic calx, while a quantity of the inflammable air disappeared.

Although any charcoal may be used in the reduction of a metallic calx, the most proper and convenient are charcoals of vegetable substances: and the charcoal of tartar is reckoned the best of all. It is, however, too costly for common occasions; and is used only when the quantity of calx is small, and we desire to perform the operation neatly, and without loss, as in assaying of ores, or in experiments with small quantities of metals:....and the operation is performed in a crucible. The reason why charcoal of tartar is the best, is, that it contains an alkali in such quantity as renders it fusible. It therefore applies itself more closely to the metallic matter, and also dissolves or melts any earthy matter which may happen to be present; in consequence of which fusion the particles of reduced metal more easily sink to the bottom of the mixture, and unite there to form one mass, called in this case a **REGULUS**. The charcoal of the tartar prepared for this purpose is called **BLACK FLUX**.

But in the large way of working, when tons of metallic calces are to be reduced, they are simply heated in contact with the fuel, and intermixed with it. In the great iron furnace, the ore, broken into small pieces, and mixed with substances which

promote the fusion, is thrown into the furnace ; and baskets of charcoal, or coaks, in due proportion, are thrown in along with it. A part of the bottom of the furnace (which is also the narrowest) is filled with fuel only. This being kindled, the blast of the great bellows is directed on it, and soon raises the whole to a most intense heat. This melts the ore immediately above it : and the reduced metal drops down through the fuel, and collects at the very bottom.....The rest sinks down, to fill up the void left by the consumed fuel and metal. Thus it comes in the way of the bellows ; and here it is raised to the same intensity of heat, and melts, and is reduced, in its turn. More ore and fuel are supplied above : and the operation goes on, till the melted metal at the bottom, increasing in quantity, rises almost to the aperture for the blast. It is now let out, by piercing a hole in another side of the furnace, close to the bottom.

There is an opinion among the chemists, founded, as they say, upon experience, that the less calcined calces are most easily reduced ; and that the calces of some metals, if exposed to the action of heat and air for a long time, can hardly be reduced at all, or not without a considerable loss. Hence the notion of a *mercurial principle*, &c. in metals, which they imagined to be partly expelled and lost by violent calcination. I suspect, however, there is another more simple reason for the loss or diminution of the metal, which is, that all the metallic substances, whether calcined or not, have more or less of volatility, and are liable to suffer a loss by evaporation, when they are long exposed to the action of heat and air.

After thus describing the calcination of the metals in general, and the reduction of them again to the metallic state, I have been accustomed to mention the opinions which have been formed of the nature of these operations, and the arguments and proofs on which these opinions are founded.

The most distinct and plausible opinion, which prevailed among the chemists for a considerable period, was that of Dr. Stahl, similar to that which he entertained concerning the nature of the inflammable substances and of inflammation, viz. that the metals are compounded substances, consisting of that matter which was called the calx, and of the phlogiston ; and

that they had their metallic qualities from the principle of inflammability; and that during calcination, this principle was separated from them; and therefore the basis or calx of the metal appeared in its separated state, deprived of the metallic qualities; but that in the operation of reduction, the calx recovered again from the charcoal, or other inflammable matter, the phlogiston which it had lost, and by this recovery, was restored again to the metallic state.

This appeared so far a plain intelligible account of the matter. But there was one material fact, which was a very great difficulty in the way of this theory. The fact I mean is, that the quantity of calx is greater than that of the metal,...one hundred pounds of lead, for example, produces 110, or 112 pounds of calx.

Different attempts were made to get over this perplexing difficulty; some of them very extraordinary, and almost incomprehensible, *e. g.* that the principle of inflammability was not only destitute of weight, but that it had the power of diminishing the weight of bodies to which it was added, &c. *

All these difficulties proceeded from their not having yet studied the part which air performs during calcination. This was not sufficiently done until of late, when the nature and powers of the different airs, or elastic fluids, became so much the subject of inquiry.

Among the experiments which this inquiry has occasioned, it was soon discovered by Dr. Priestley, Scheele, and Beccaria, but especially by M. Lavoisier, and other French chemists, that when a metal is calcined, it always absorbs and fixes a part of the air which contributes to its calcination and is necessary to it; and that the increase of weight in the calx is always equal to the quantity of the air absorbed.

* Nor could any valid objection have been made to this explanation, however unlike our more familiar notions, had not Sir Isaac Newton made experiments on pendulums of all different kinds of matter, metals, and the calces of metals, and found that all vibrated alike, if of equal length. Chemists acquiesced, however, in this explanation by Stahl; because few, if any of them, were mathematical philosophers, and as few of the mathematicians were experienced chemists. EDITOR.

Dr. Mayhow of Oxford observed this in the cases of antimony and lead, and suspected that it was so in all,....1674.

It has further appeared from such experiments, that it is always oxygen gas which the metals attract in this manner. They are calcined most easily and quickly in pure oxygen gas; and cannot be calcined in any other, except when it contains a mixture of the oxygen, as atmospheric air does. When calcined in a limited quantity of atmospherical air, therefore, they extract the vital part from it, after which the rest of the air has no more power to calcine them. *

It has also been proved in the clearest manner, that oxygen gas can be extracted from the calces of metals; from some by heat alone,....the calx at the same time recovering its metallic form. This happens to mercury, silver, gold, platinum. From others, the oxygen gas may be extracted by an elective attraction; as happens in lead, the calx of which, viz. minium, affords oxygen gas by the action of sulphuric acid assisted with a moderate heat. On the other hand, in the reduction of metallic calces by the action of charcoal, a great quantity of elastic aerial matter is extricated from the materials, which is carbonic acid, that is a compound of oxygen and charcoal. All these particulars are now completely proved by many experiments: and upon these M. Lavoisier and his friends founded their new system concerning calcination and reduction, totally opposite to that of the older chemists. The new opinion is, that the metal is not a compound, but a simple body; that the calx is compounded of the metal and oxygen extracted from the vital air; and that the heat and light are no proof of a principle of inflammability. They are extricated chiefly from the oxygen gas, which is supposed to have an extraordinary capacity for heat, and which, as being an elastic fluid, contains a great deal besides in a latent state.

In reduction again, the new doctrine is that the oxygen is separated from the metal, and nothing else happens or is necessary to the recovery of the metallic state; and therefore, in the

* A similar doctrine was maintained by Mr. Bayen, a French apothecary. *Journ. de Phys.* III. 120,....IV. 487,....VII. 390.

reduction of mercury, silver, gold, and platinum, which have but a moderate attraction for oxygen, heat alone is sufficient to separate it. Other metals cannot be reduced by heat alone, on account of their having a strong attraction for the oxygen, and retaining it too strongly to admit of its being forced off by heat: but such are commonly reduced by the action of charcoal, aided by heat; and then the carbon attracts the oxygen from the metal, and forms carbonic acid with it. The production of carbonic acid gas in this manner has been ascertained by numerous and incontestable experiments. And when inflammable air is employed, the basis of this air, the hydrogen, acts like the charcoal, by its strong attraction for the oxygen that is in the calx. They unite together, and form water. This also has been ascertained by many experiments.

A change of some names has been proposed in consequence of this theory, viz. *calx* and *calkination* are to be set aside, and calcined metals or calces are to be named OXYDS; *des oxydes*, in French; *oxydum*, *oxyda*, in Latin. But this term of oxyd is applied by the French chemists to every compound, whether metallic or not, that contains oxygen in less quantity than that which gives acidity.

On the whole, this system is much more directly and plainly supported by facts and experiments than the ancient system of the chemists.

The only fact which the French theory has not yet explained is, the effect of light in reducing the oxyds of metals. There are several examples of it, in consequence of which it is supposed, by the defenders of the old doctrine, that the light unites itself to the metallic matter, and thereby restores it to the metallic form. But it must be acknowledged that when metallic oxyds are reduced by light, oxygen gas is always detached; and the French chemists say, that the light affects the reduction, not by attaching itself to the metallic oxyd, but by some power which it has to occasion the separation of the oxygen, perhaps by joining with it, and thus forming with it oxygen gas.

One fact more, which has been discovered by the experiments lately made on the metallic oxyds, must not be omitted, viz. That many of them, when once formed, are capable of attract-

ing carbonic acid, and of uniting with it, and even of being dissolved by it in water, like the alkaline earths.

I now proceed to consider the properties of metals respecting their mixture with other bodies.

The first class of the objects of chemistry,...the salts, and of these the acids, are found to have the greatest activity with regard to metallic substances, and to produce the greatest variety of effects.

To give a general idea of those effects, I may begin by saying that there is a chemical attraction between metals and acids; that metals are capable of uniting with acids, much in the same manner as alkalis and the alkaline earths are; that they are disposed to form with them saline compounds, many of which readily crystallize; and in most, the natural activity or corrosiveness of the acid is very sensibly abated by its adhesion to the metal, though, in general, not near so much as in the salts composed of alkalis or earths.

The chemical combinations of metals with acids are commonly named *solutions* or *dissolutions* of the metals, on account of their being commonly produced by putting the metal mechanically divided, or with an increased surface, into the liquid acid, which acts on it as a solvent. The action of the acid is promoted by gentle heat, and also by annealing or softening the metal before it is put into the acid. This last practice is useful, probably, by diminishing in the metal that species of cohesive attraction called *hardness*, which is an antagonist to the power by which the dissolution is performed. At any rate, the fact is certain. If we take a few of the small cast iron tacks, (made of the white metal) which have not been annealed, and as many of the same tacks long annealed, and put each parcel in equal quantities of acid, the last will be found much more diminished in weight than the other in the same time. Moreover, the unannealed nails seem to resist most at the surface; and when half dissolved, preserve their form completely. In this particular metal, indeed, a spongy nail remains coherent to the last.

In performing these dissolutions of the metals, we find also that in many cases there is a mutual saturation, as with the acids and alkaline substances; a certain quantity of acid

being capable of dissolving, and converting into a saline compound, a certain quantity only of the metal; and the metal on the other hand, neutralizing or mitigating a certain quantity only of the acid. This does not happen, however, in all the compounds of metals with acids. In many of them there is no fixed point of saturation, the same quantity of metal being capable of combining with different proportions of acid, and forming compounds which differ in appearance and other qualities, according to the proportion of acid which they contain. Even in this case, however, it is not so properly said that there is no fixed point of saturation. The fact would be better expressed by saying, that the saturation is not confined to one proportion. For, in these cases, we find that when a certain proportion is attained, the addition of more acid, for example, dissolves the salt, without changing its properties, till we reach another proportion, when a manifest change of chemical and other properties ensues. Sometimes we shall have a third proportion, in which a kind of saturation obtains. This resembles the combination of water and salt, in the states of crystal and solution, and in the combinations of heat, inducing solidity, fluidity, or vapour. When the proportion of acid is large, the acid is less mitigated, and the compound is more soluble in water, and in some cases deliquescent. When the quantity of acid is very small, it is much mitigated, and the compound has little or no solubility, the metal being only divided by the acid into a powder, and not dissolved. In this case, that is, when the acid divides the metal into a powder, but does not dissolve it, or render it soluble in water, it is said to *corrode* it; and the metal is said to be *corroded*.

It must be understood further, that every metal is not equally disposed to unite with each of the acids. Some of them can be combined with all the acids, or any of them; but others with a certain number of them only. And there are some which are not acted upon in the least, except by one or two, or by certain mixtures of the acids with one another.

Those metals which are capable of uniting with a number of the acids generally have the strongest attraction for the muriatic, and next to the muriatic, for the sulphuric. The

acid of sugar, or the oxalic, and the tartarous acid, and the phosphoric, are also strongly attracted by the metals in general. The nitric acid, although it dissolves a great number of the metals readily and easily, is not so strongly attracted and retained by them. It is more easily separated from them by heat or otherwise. The muriatic, when combined with them, is so strongly retained, that it is not separable by heat, but renders the metallic matter volatile along with itself.

Among several metals which can be dissolved by the same acid, great differences are found in their attractions for it; and some of them can be employed to precipitate others in a certain order. Zinc or iron, for example, can be employed to precipitate silver, or quicksilver, or copper, or lead, from the nitric acid. Lead precipitates copper, quicksilver, or silver. Copper precipitates these two last; and quicksilver precipitates silver. Zinc is therefore supposed to have the strongest attraction for the acid; next to zinc, iron; next lead, copper, mercury, and silver.

There is a remarkable circumstance which distinguishes the solution of metals in the acids from the solutions of alkaline and other substances. While metals are dissolving in acids there is, in many cases, a violent effervescence, ... an effervescence sometimes as strong as that which attends the action of acids on common alkalis or calcareous earths. It is, however, quite different in its nature from the effervescence of alkalis or alkaline earths. It is not produced by the separation of fixed air or carbonic acid. The metals in their metallic state do not contain any. These effervescences are explained in a very satisfactory manner by a great number of the modern experiments, which shew that either a part of the acid or a part of the water is decomposed by the dissolving metal, which attracts to itself a part of their oxygen, and is thereby changed into an oxyd, (formerly called *a calx*); which oxyd, as a peculiar substance, is dissolved by the remaining acid, or is united to it. When the oxygen is taken up by the metal from a part of the water, hydrogen gas is produced in the effervescence, as you saw lately when iron was dissolved in diluted sulphuric acid. When the oxygen is taken up from a part of the acid, the acid is partly decomposed; and a different elastic fluid, or other matter is pro-

duced, peculiar to that acid. All this will be more fully explained as the cases occur. (*See Note 50. at the end of the Volume.*)

We find reason to be satisfied that this theory is well founded, when we examine the state to which the metals are reduced by being dissolved. A metal, while dissolving, is always calcined, or oxydated, more or less ; in many cases, it is true, to a very small degree only : but in every case, some degree of this change does happen to it ; for, if we precipitate the metal by the action of a pure alkali, we always get it in form of a calx : and we get it in nearly the same state if we expel the acid from it by the action of heat alone. And when, on the other hand, we change the metal into an oxyd by the action of heat and air, before we apply the acid to it, there never is an effervescence ; the metallic matter generally dissolves quietly, in some cases more easily than the metal itself, when put into the same acid. But this happens only when the metal is calcined in the slightest degree possible. If much calcined, it dissolves more slowly and difficultly, and requires a greater quantity of acid to its dissolution than the metal itself would have required.

We may further remark here, that the different acids act on the metals with different degrees of quickness and violence. The action of the nitric is generally the most quick and violent, and most effectual in oxydating the metals : next to this the sulphuric. The muriatic acid generally acts in a more slow and languid manner on the metals in their metallic state. This appears plainly to proceed from its having less of the oxygen to impart to the metal ; for if the metal be first slightly oxydated, no acid whatever unites with it so readily and strongly as the muriatic acid. We have a proof of this, when we add muriatic acid to a metal already oxydated by another acid, as the nitric, or even the sulphuric acid. There are also particular states or conditions of the muriatic acid, in which it acts more readily and powerfully on the metals than it does in its ordinary watery state. We apply it, for example, in some cases, in the form of dry and hot vapour, as in cementation, described in my general account of chemical operations. And there are other processes soon to be described, by which we add oxygen to the

muriatic acid. By this its power to penetrate and dissolve the metals is greatly increased.

The compounds, or the solutions of metals with acids, are of different colours, when made with different metals, or with the same metals in different states of oxydation.

Fourcroy (*Annales de Chymie. tom. x. on Mercurial Precipitates*) mentions an opinion of the French chemists, that the colour of the solution or compound is similar to that of the oxyd contained in it; and that when, from such solutions or compounds, a precipitate is produced of a different colour, this proceeds from a change the oxyd has undergone in its degree of oxydation, while it was precipitated, or immediately after. Yet he says, (page 309, *et alibi*) that Turbeth mineral, or sulphat of mercury, with excess of oxyd or calx, is soluble in 2000 waters, and forms a colourless solution. Caustic alkalis precipitate from this solution a grey oxyd. This colour indicates some degree of deoxygenation. Fourcroy imputes this change to the caustic alkalis: but this is no explanation.

The compounds of metals with acids may be decomposed in general without difficulty. The acid and oxyd are united together in the greater number of cases, by an attraction that is not very strong, which is plain from its being overcome by many other attractions; by alkalis, the alkaline earths, and even by some of the inflammable substances, which are disposed to unite with acids. If fresh calcined litharge (which is an oxyd of lead) be ground to fine powder, and be put into a solution of lime in muriatic acid, we find the lime precipitated in a caustic state: and the liquid now contains a compound of lead and the acid. Or if sea salt be digested with litharge, we procure a caustic mineral alkali. (*Scheele on Fire, 174.*) This explains the corrosion of the lead pipes which convey water. It very commonly holds both of these muriats in solution.

Heat alone is sufficient, in many cases, to separate acids from metals. All this proves that the attraction between them is not strong, in the greater number of cases. It is probably in consequence of this moderate attraction, that in some of the compounds of metals with acids, the acid is very little mitigated, the compound being nearly as cor-

rosive, when applied to animal substances, as the pure acids themselves. In this way we have obtained some of the most useful potential caustics and escharotics employed by the surgeons.

This being a very general property of the metallic salts, and being a property purely chemical, because it is equally effective on the dead and on the living subject, has attracted the attention of the chemists, and they have attempted to discover some general principle on which it depends. Mr. Berthollet, unquestionably one of the most eminent, published a dissertation on this subject in the *Journal de Medicine* in 1779. He ascribes it to the action of the acids on the phlogiston contained in animal and vegetable substances; and supports this by a very judicious series of experiments. The doctrine of phlogiston being exploded, this explanation, as far as it was valid before, is easily accommodated to the new doctrines: and we must ascribe the corrosive power of the metallic salts to the action of the oxygen which they contain. It is very true, that the action of oxygen produces very remarkable effects on animal and vegetable substances. But I do not think that they have a great analogy with the action of the highly corrosive metalline salts, such as that formed of mercury with the sulphuric, nitric, and muriatic acids, or that formed by silver and the nitric acid. Some of those salts are most highly corrosive when they contain the smallest quantity of oxygen, a quantity so small that they are scarcely saline, and very strongly united. Others are more corrosive when they are truly saline, and contain not only oxygen, but also the distinguishing ingredient of the acid. And others are so far from being corrosive in either state, that they promote the healing of wounds and sores, seeming friendly to the functions of organised substances. Perhaps the corrosiveness is sufficiently accounted for, when we ascribe it to the acid itself. Nor is it incongruous with the general course of chemical facts to say, that in some of these compounds, new properties are induced, differing from those of either ingredient.

The other order of simple salts, the alkalis, have not so much dissolving power with regard to metals as the acids. They are more commonly employed to precipitate metals

from acids, which they do by their great superiority of attraction.

The separation of a metal from solution in an acid, presents such a variety of phenomena, that I can scarcely bring them under general rules, and shall therefore notice them as they occur in treating the several metals. I observe, however, in this place, that in most cases, a smaller quantity of alkali is sufficient for separating a metal from a given quantity of acid, than suffices for saturating this quantity of pure acid. The precipitate is in the form of an oxyd, and in these cases, has decomposed part of the acid. It is only the remainder that employs the alkali to separate it from the metalline oxyd. How this is effected, even in those cases where water is decomposed, and inflammable air is produced, must be considered as a difficulty still remaining in the new doctrines of the French chemists.

The alkalis themselves may also, in some cases, be made to act as solvents, and will dissolve most metallic substances very perfectly. They act most powerfully in their caustic state, especially if applied with a melting heat. In the state of watery solutions, they act but weakly in general, though there are some of the metals which they dissolve very perfectly even in this way. And if the metal be previously oxydated, especially by acids, there are few of them that will not yield to the action of alkalis.

Thus it happens, in many cases, that when we precipitate a metal from the solution in an acid, by a caustic alkali, if we put in too much alkali, we redissolve the metallic oxyd. The volatile alkali does this in most cases. A certain preparation of alkali, which will be described in due time, ensures the alkaline solution.

In a dry melting heat the alkalis are powerful solvents of the metalline calces, and form with them a variety of coloured glasses.

Among the compound salts, borax is found useful in the melting of gold and silver, and in soldering these and other metals. Its usefulness is remarkable, especially when filings or small pieces are to be united by fusion. It helps to make them melt more readily, and to join all together the more completely, and with the least loss. The borax promotes the

union of the melted particles or globules of the metals, by making their surfaces clean and bright, and preserving them in that state. The necessity of this is plain in mercury, which the smallest foulness hinders from uniting. Its globules are then rather disposed to separate into smaller globules when we attempt to bring them together. And the borax effects this, by covering and defending the metal from air, and thereby preventing the formation of any calcined crust or pellicle, and likewise by dissolving any matter of this kind which is already formed; borax having much power to dissolve and melt the earthy substances and metallic oxyds. By spreading itself also over the surface of the crucible, it gives a smooth glazing, which allows the metal to be poured out.

The other neutral salts are not much disposed to act on metallic substances, except when assisted by a strong heat; but, with its assistance, those which contain the acids that have the greatest power over the metals are disposed to act upon them, and dissolve or corrode them, more or less, the acids being loosened by the heat. Glauber's salt, vitriolated tartar, common salt, and digestive salt, produce this effect. The effects of nitre and ammoniacal salts are more remarkable. Many of the metals, when they are thrown into melted nitre, are inflamed or burnt, as has been already seen; and the metal is reduced to the state of an oxyd. This oxydation concurs with the effects which you formerly saw in the mixtures of nitrous acid with alcohol, to shew how easily the nitric acid is decomposed. No part of it is to be found in the crucible, if enough of metal have been employed. We find only a caustic fixed alkali, sometimes, indeed, tainted by the metallic oxyd which it has dissolved. Hence we must conclude that the metal is oxydated by attracting the oxygen of the nitric acid, and thereby allowing the nitrous air or the azote to escape. This escape must be considered as the cause of the deflagration.

The effect of common sal ammoniac upon the metal is easily understood. The attraction of the acid for the volatile alkali is scarcely greater than for some of the metals or their oxyds. Therefore, when one of them, in fine particles, is mixed intimately with sal ammoniac, and

distilled, we obtain the volatile alkali in a caustic form ; a proof, by the way, that metals do not yield fixed air in their effervescence with acids. In this decomposition of the ammoniacal salt, the effect is brought about by the heat, which volatilizes the alkali. The vitriolic ammoniac exhibits the same appearances.

The oxyds of some metals, when put into a watery solution of sal ammoniac, act with great variety of appearances, which will be explained afterwards.

With respect to the second class of the objects of chemistry, the earths, the relations of these to metals in general has been, in some measure, pointed out already, and amounts to a very few propositions only. I have already observed, that some of the alkaline earths have a stronger attraction for acids than most metals. I also had occasion to notice that melted earths and melted metals cannot be mixed, at least so long as the metals retain their metallic form. But when they are in the form of oxyds or calces, they can easily be mixed with melted earths or glasses; and some of them have even great power in this state to promote the fusion of some of the earths, or to dissolve them in a melting heat. They are, therefore, added to some of the compositions, for making glass in some cases, in order to make it more perfect and transparent, and in others, to give it colours, in the imitations of the natural gems. When metallic oxyds happen to be mixed and combined in considerable quantity with vitrified earths, they can be separated from them by fusion with charcoal or black flux. Thus, a piece of fine English flint glass, or the false diamonds called *Paris pastes*, being reduced to powder, and urged with a strong heat, in contact with charcoal or black flux, will be decomposed, and we shall find a button of lead at the bottom of the crucible.

Among the substances of the third class, the inflammable, some serve for the reduction of metallic oxyds. But, excepting this use of them, none but sulphur, phosphorus, and charcoal in some cases, are remarkable for a disposition to unite with any of the metals.

Sulphur shews a strong attraction for most metallic substances; and may be united with most of them, readily and

intimately, in the way of fusion. And though the heat be not sufficient to melt the metal, but only the sulphur, if the metal be only divided into small pieces, the sulphur penetrates it, and entirely changes its appearance, examples of which shall be given hereafter.

In making many of these compounds of sulphur and metal, a great quantity of heat is extricated from the materials, which make them become ignited, and glow as if they were inflamed. This was mistaken at first for a real inflammation. The most remarkable of these experiments were made by Van Troostwick and Dieman. They mixed sulphur with different metals, in a closed phial, or in an exhausted tube hermetically sealed, or in a tube filled with hydrogenous or azotic gas, or carbonic acid. With an external heat, by no means very great, the sulphur melted, and, after some time, the combination with the metal took place. In that moment, the whole broke out into a bright glow, in some cases brilliant, and almost like a real deflagration. Three parts of copper to one of sulphur produced the brightest light. Lead also, and tin, and especially zinc, produced a bright flame. (*See Note 51. at the end of the Volume.*)

In the new language of chemistry these compounds are called *sulphureta*, for the Latin word, or, in the singular, *sulphuretum*. And our chemists, who have adopted this language, call them *sulphurets*.

Sulphur, in such experiments, not only shews an attraction for most metals, but like other bodies which have a power of this kind, it is found to attract different metals with different forces. And some metals can be employed in many cases to separate sulphur from others, in a certain order. When this separation is performed in the way of fusion, in a crucible, the sulphur, uniting with the added metal, which it attracts most, forms a matter which flows uppermost; the other metal separates and falls to the bottom, or forms a *REGULUS*. But this method of separating sulphur from metals is not the necessary or only method in all cases. There are many, in which the sulphur can be separated by heat alone: and it is more usual to expel it in that way.

Gold, platinum, and zinc, are exceptions to the general account I have given of the relation of sulphur to metals.

Sulphur cannot be made to penetrate these three, or unite with them, if it be applied pure, and these metals are in their metallic state. But when sulphur is combined with an alkali, this compound acts much more powerfully as a solvent, in the way of fusion, upon metallic substances in general; and even the three I just now mentioned are readily dissolved by it. The different metals, when dissolved by this compound, unite with it with different degrees of force, in the same order as sulphur does. Thus, we have it in our power to separate the metals from it also by one another. The best proportion for dissolving metals is equal parts of sulphur and alkali.

The management of phosphorus, in combining it with metals melted or made red hot, requires much caution. The best way is to cut it into bits of four or five grains weight, and keep them under water; and when they are used, to take out one at a time, wipe it dry with bibulous paper carefully, and introduce it into the crucible with a long pair of pincers, plunging it to the bottom. The greater part of it is always dissipated; but some combines each time. Perhaps a composition, which will produce phosphorus, hard pressed into the bottom of a crucible, would answer better. The crucible being made hastily red hot, the melted metal may be poured into it, and the heat continued. The phosphorus would thus be presented to the metal in its nascent state, which is found to be favourable in most cases of difficult combination. The fusibility of the metal is improved by this addition.

By Pelletier's experiments (*Mem. de l'Acad. des Sciences*) 100 grains of platinum are changed into an easily fusible phosphoret, by the addition of eighteen grains of phosphorus: and 100 grains of gold require only four gains of phosphorus to change them into phosphoret. These compounds, if exposed a long time to the action of heat, burn at their surface until all the phosphorus is consumed; and the above metals remain in their ordinary state.

In the experiments which have been made by mixing metals with one another, it appears that metals unite in general with one another, and this in every proportion. But there are some exceptions, as iron and lead, iron and mercury, lead and cobalt, nickel and cobalt, cobalt and bismuth. The

mixtures are of different specific gravity from what corresponds with the ratio of the composition. * In general, the specific gravity and density are greatly increased, so that in many cases the compound is denser than the densest of the ingredients. Thus the density of tin is 7363, and that of brass is 8006. But the density of a mixture of two parts of brass and one part of tin is 8916. The proportion of the composition should have given 7793 *. They are also more fusible: hence they are employed as solders,...for gold, we employ a mixture of gold and silver,...for silver, silver and mercury,...for copper, brass,...and for brass another still more compounded,...for either lead or tin, a mixture of both.

Mixtures of metals, in general, can also be calcined more quickly than the same metals in their separate state; of which you have an example in the mixture of lead and tin, which burns like a bit of turf. If you would wish to know the cause, I shall hazard a conjecture. I am inclined to think that this effect is produced by the chemical attraction of the metals for one another, which counteracts the cohesive attraction of each of them, and diminishes its force, and thereby gives advantage to another chemical attraction,...their attraction for oxygen. That their cohesive attraction is diminished by their union with one another is evident, the mixture being always more fusible than the separate metals†.

The method of separating metals from one another again, is very various in the different cases, and depends upon certain particular properties and differences of the metals which are to be separated. Thus in some cases, difference of fusibility is made the means of separation: thus lead is separated from copper. In others, difference of volatility: Thus mercury is separated from antimony. In many others, difference of solubility: Thus gold and silver are separated by aquafortis, or aqua regia, or sometimes by sulphur; or gold and iron by sulphur and lead.

* It is also an almost universal fact that the cohesion of the compound is greater than in the proportion of the composition. In the ductile metals, whose cohesions are not extremely different, the cohesion of the compound exceeds that of the firmest of the ingredients. Thus the mixture of twelve parts of lead with one part of zinc is twice as coherent as the zinc....EDITOR.

† Yet the mixtures are generally more dense and much more coherent than the ingredients separately....EDITOR.

Other separating operations, which are frequently performed, depend on different degrees of their attraction for oxygen, and more or less disposition to unite with it; that is, on a difference in their tendency to calcination. Thus lead, and most other metals along with it, are separated from silver and from gold: and thus copper also is refined from admixture of the coarser metals. In most cases of separation performed in this manner, the process is called **SCORIFICATION**.

The mixture is exposed to a violent heat and to a current of fresh air, which causes the surface to tarnish, and then to gather a film or scale of the more calcinable metal. This is usually blown to one side of the melted mass, as it forms, by the bellows. It is succeeded by more; and this continues, till the less calcinable metal be as much purified as is possible by this operation. What is thus blown or raked off, is called **SCORIE, SLAG, DROSS**. It is not always a slag or filth,...but a portion of the metal, of the same purity, but no longer perfectly metallic, but a compound of the metal and the oxygen of the atmosphere.

The rusting of iron and other metals is a change of precisely the same kind, and is produced by the same cause. It is very remarkable in iron, because this metal also decomposes water very fast, and therefore rusts very fast in damp and warm air.

You are now informed of the general character and qualities of the metals. We must now attend to their natural history, or the different states in which they are found in nature.

The first remark we have to make on this subject is, that few of them are produced by nature in a state of purity. They are most commonly found in the form of what are called **ORES**, which are compound minerals, in which the metal is intimately mixed with other substances, so as to have neither the malleability, nor the other qualities of the metals, except sometimes a degree of the shining metallic appearance.

Frequently the ore is an oxyd of the metal, and only requires the operation of reduction to be performed in order to give it the metallic properties.

The ores of metals are commonly found in the veins of the hardest mountains, and hardest stony strata. They are generally separated from the rock, being intermixed in the vein with a quantity of spar or quartz, or sometimes a softer matter. When a spar involves the ore, it is in some cases a calcareous spar,...in others a fluor; but more frequently a sulphat of barytes. When the ore is involved in quartz, it is sometimes a pure quartz, but oftener an intermixture of quartz with some or several of the spars; and often also we find intermixtures of the spars without any quartz. These matters, thus accompanying the ore in the vein, are called in general the **MATRIX** of the ore, and by the English miners, the **RIDER**. The manner in which the ore and matrix are interspersed through the vein is altogether irregular. In some parts of the vein, the whole wideness of it is filled with ore; in other parts, with matrix alone; in others the ore and matrix are found together, in all the variety of proportions and modes of intermixture that can be imagined. Such mixtures are called *brangled ores*.

The ore being separated and picked out from the matrix to be examined by itself, is commonly found to contain, not only the metal on account of which it is valued, but, along with it some of the other metals, and a considerable proportion of sulphur or arsenic, or both of these, and sometimes a small proportion of earthy matter.

These ingredients are intimately united in the ore, that is, they are chemically combined with the metal; and the operations by which the metal is extracted are processes for separating these matters from it.

But before we can well understand these processes, it is necessary to have some knowledge of arsenic. It will be found to be a metal; and it will be very convenient to make it the first subject of our study.

METALS.

GENUS I.....ARSENIC.

ARSENIC is a matter which resembles the saline substances so much by some of its properties, and the metallic by others, that the chemists were long in doubt to which class it should be referred. Dr. Boerhaave describes it among the sulphureous minerals, probably on account of its being often found in its natural state combined with sulphur. But when the arsenic is found pure, or is purified by art, it is widely different from sulphur.

The nature of arsenic was very little understood till Mr. Macquer published some papers in the Memoirs of the Royal Academy, containing a number of experiments he had made on this mineral. And more lately, Dr. Scheele, of Sweden, communicated his instructive experiments on it to the Academy at Upsal.

The ordinary appearance of arsenic is that of a compact heavy matter, of a white or yellowish colour, and having the glassy fracture, sometimes transparent, oftener of an opaque white. Exposed to heat, under the ordinary pressure of the atmosphere, it becomes soft, or approaches to fusion, when very near the lowest degree of ignition. But in the same heat also, it begins to evaporate in white fumes, of a sickening heavy smell, thought to resemble garlic; and is thus totally converted into vapour by degrees, without becoming perfectly fluid. The fumes, if confined and condensed by cold, form a white powder, or chalky-like matter, which afterwards, if the vessel be of a proper shape, is softened and compacted by the heat into a whitish glassy-like substance. It is always by sublimation that it is brought to this form.

The qualities, by which arsenic resembles the metals, are, 1st, Its weight. 2dly, A capability to be metallized, or to assume some of the metallic qualities, such as the metallic

opacity and bright reflecting surface, and a density or specific gravity similar to that of the metals. It also becomes a conductor of electricity, and fit for mixing intimately with the other metals, which it will not do in its ordinary state.

It may be so far metallized by several processes. Mr. Macquer describes one in which this effect is produced by means of oil and sublimation. I have succeeded equally well by subliming the arsenic repeatedly with charcoal dust.

But one of the best is Scheele's process, described by Bergmann. White arsenic is put into a crucible, with thrice its weight of black flux; and an inverted crucible is luted to it. The lower crucible is set on the fire, and slowly raised to a red heat. But the upper crucible must be defended from it, by means of an iron plate, having a hole exactly filled by the rim of the lower crucible. In this manner, the upper crucible will be covered within with a crust of regulus perfectly clean, and in a crystallized form. And it may be detached from it at once by a dexterous knock.

Arsenic, when thus made to assume the metallic appearance, is quite brittle like several other metals, and its surface is liable to tarnish; so that it loses its lustre very soon, if exposed to the air. Or if we evaporate it in the open air, the vapour may be at once condensed into white arsenic; also if sublimed with fixed alkali. By these processes, therefore, it returns immediately to its former appearance.

These several particulars give us reason to consider arsenic as a substance of a metallic nature; and to view it, when in its common form, as in a calcined state, or as an oxyd of arsenic. But it differs from the oxyds of the other metals, by having qualities decidedly saline. We have a clear example of this, in its solubility in water, and in its action upon the alkaline salts, and upon nitre. The solubility of white arsenic in water appears, if we beat it to powder, and boil it in the water. We thus learn, that it may be completely dissolved in fifteen times its weight, and from this solution the arsenic may be obtained in the form of crystals. Arsenic unites also with watery solutions of alkalis, especially caustic alkalis, and with lime-water; and its volatility is somewhat repressed by the union.

Its action upon nitre was thought the most remarkable, as it shews that arsenic may be employed to decompose nitre by expelling its acid. Equal parts of nitre and arsenic being mixed in fine powder, and exposed to heat in a retort, the acid of the nitre arises very volatile and elastic, and of a deep red colour; and does not condense unless there be water in the receiver. It tinges water a fine blue. When the whole acid is expelled, there remains melted a white mass in the retort, composed of arsenic and fixed alkali, which dissolves in water, and easily crystallizes into very regular crystals. It melts in a crucible, and forms a transparent fluid, and is very fixed, emitting no arsenical fumes; the arsenic appearing to be very strongly combined with the alkali. Again, the qualities of this compound are quite different from those of a compound formed by combining white arsenic, with a pure alkali. It requires for its production not only the acid of arsenic, but so much of it as to make it acidulous and crystallizable. The other compound is called by Macquer **LIVER OF ARSENIC**. It might as well be called **ARSENICATED ALKALI**. It has a particular weak but heavy smell. If heated in a crucible, it is not fixed like the other, but emits arsenical fumes in abundance. When dissolved in water, it will not crystallize; but, when evaporated, becomes pasty or gelatinous. Mr. Macquer was at a loss to explain how this happens, particularly why the crystallizable salt, formed by expelling the nitric acid by arsenic, should be different from common arsenicated alkali; and why arsenic does not decompose common salt, though it decomposes nitre.

But the whole of this subject has been cleared up by the experiments of Scheelè, who made much more progress in discovering the nature of arsenic, and has given us principles by which all the phenomena are explained. He learned, by a series of instructive experiments, that one reason why the crystallizable arsenical salt, and the common arsenicated alkali, have not the same property, is, that the arsenic, in the crystallizable arsenical salt, has undergone a change from the state of common white arsenic; the acid of the nitre having acted upon it as it does upon sugar and some other substances, so as to change it into an acid. Of this he gave the most satisfactory demonstration, by applying the nitric acid to white arsenic by other

different ways, by which he changed it into an acid, which he obtained separate from any other matter: and afterwards, combining this acid with the vegetable alkali in sufficient quantity, he formed a perfectly crystallizable arsenical salt.

He contrived two processes by which he changed white arsenic into an active acid. The first of these is entirely an imitation of the process by which sugar is changed into an acid, with this difference only, that some muriatic acid is first employed to dissolve the arsenic, that the nitric acid may act on it with more advantage.

Scheele's process is as follows: Into a tubulated retort, fitted with a receiver, put two parts of powdered white arsenic, and seven of muriatic acid; and dissolve by a gentle boiling heat. When all is dissolved, pour back what is in the receiver, and add three and one half parts aquafortis, and distil. The nitric acid rises in red fumes, and after some time they cease. Now add one part arsenic, and one and a-half aquafortis. Red vapours arise again. Distil to dryness, and make the retort red hot.

In the retort you have the arsenical acid, fixed in the fire, and deliquescent in the air, and soluble in twice its weight of water.

Mr. Pelletier, however, says that we succeed equally well by using the nitric acid alone, in the proportion of six parts of the acid to one of the white arsenic. The acid comes off in red fumes of nitrous gas, and the white arsenic assumes the true characters of the arsenical acid (so it is now called.) It must be kept a good while in a strong heat, to expel all the redundant nitrous acid. (*Fourcroy* II. 507. *Ed.* 1786.)

This is an exact enough account of the phenomena, and perfectly instructive in the nature of the operation. But having practised both methods, I agree with Dr. Scheele, that his previous solution in muriatic acid enables the nitric acid to act on a much greater quantity of the arsenical oxyd.

The manner, in which this process produces its effect, is sufficiently evident. White arsenic must be considered as a metallic oxyd, containing a very moderate quantity of oxygen, and capable of a higher degree of oxydation. I always viewed it in this light; and on this principle, I explained Mr. Macquer's experiments, and the effects which it produces with nitre; a part of which is the change of the nitric acid into nitrous

acid, in consequence of the abstraction from it of a part of its oxygen, attracted by the arsenic. In Scheele's process, the nitric acid alone supplies oxygen to the arsenic, and thus oxydates it to the greatest degree of which it is capable; in which high state of oxydation, the abundance of oxygen which it contains, gives it the qualities of an acid, and deprives it of attraction for other acids, but disposes it to unite strongly with alkalis. This is the proper explication of the process according to the principles of the new theory; and there is an experiment described by Scheele, which gives great support to the French explication of the phenomena, and establishes it without a doubt. This experiment is made with the acid of arsenic. If some of this acid be put into a retort by itself, and exposed to the action of heat alone, it endures a low red heat without change, or is only melted. But if the heat be increased, and continued, the greater part of the acid arises gradually into the neck of the retort, in the form of a common white arsenic: and while this happens, a very considerable quantity of oxygen gas is produced or extricated from it. This is certainly a clear proof, that a redundancy of oxygen is contained in the acid of arsenic, considered merely as an oxyd, since we see that when a part of it is separated by the action of heat, the acid of arsenic returns to the state of white arsenic.

I may add here, the mention of one process more for obtaining arsenic in the state of an acid. It was discovered and communicated by Mr. Pelletier. He performed Macquer's process, but used the nitrat of ammonia in place of common nitre. He thus expelled the nitrous acid, which passed over in distillation, and an arseniat of ammonia remained in the retort. But by changing the receiver, and increasing the heat, he was able to make the ammonia or volatile alkali arise in a caustic state from the arsenical acid, which remained in the retort.

This acid is now called the ARSENICAL ACID: and the compounds it forms with other substances are ARSENIATS, in the new language of chemistry. Dr. Scheele made a great number of experiments with this acid, by combining it with other bodies, and investigating its properties. He informs us that it has not a strong taste; that it dissolves slowly in water, but may be dissolved in twice its weight of that fluid; that in this fluid

state it neutralizes the alkalis and alkaline earths, and dissolves many of the metals, or unites with them, with particular phenomena, which he describes. You may see all this in his *Essays*, and an abstract of the whole in Bergmann's *Treatise on Electric Attractions*; and in Nicholson's *Chemistry*, article *Arsenic*.

Scheele found, in attempting to dissolve some of the metals in the watery solution of this acid, that it oxydated them, and was itself restored to the state of white arsenic; a proof that it does not retain the oxygen so strongly as to prevent its communicating some of it to other bodies that have a stronger attraction for it. We have a more striking proof of this in the result of several of the experiments Scheele made by causing the dry acid to act upon metals and other bodies. This acid is easily reduced to a dry state and can be melted into a transparent matter, like glass. If some of this dry acid is beaten to powder, and then mixed with dry charcoal in powder, or with filings of different metals, and these mixtures are heated, there is, in many cases, a strong deflagration, such as is produced by nitre with the same substances: and the acid is in a moment changed, partly into white arsenic, and partly into pure or metallic arsenic, both of which are sublimed.

Dr. Scheele discovered that Mr. Macquer's crystallizable arsenical salt, prepared with nitre, is a compound not exactly neutral, but is a little acidulated by a small surplus of the acid of arsenic: and when it is made exactly neutral, it will crystallize, but is deliquescent. And he explains how it is formed in the process with nitre.

When arsenic is in its ordinary state of white arsenic, it is soluble, in small quantity, in a variety of fluids. Boiling water, I observed before, dissolves one-fifteenth or one-twentieth. Spirit of wine also dissolves a little of it, and even oils. Aquafortis, or diluted nitric acid, also dissolves it with difficulty, but changes it more or less into acid of arsenic. The readiest solvent is muriatic acid, which dissolves oxyds of metals in general better than other acids do. It forms a compound, which can be distilled or sublimed; and sometimes condenses like oil. Fourcroy says, that calx of arsenic, that is, white arsenic, will not afford this oil; but that it is easily obtained from one part of metallized arsenic and two parts of sublimate of mercury,....the mercury being revived.

Arsenic has a disposition to mix in small quantity with earthly bodies in a vitrified state, or to act on them; and this is one of its useful qualities, a good deal of it being employed by the manufacturers of glass. White enamel is made with it, with which Delft ware is glazed; and also all the pretty ornaments, which were formerly twisted in very beautiful scrolls, in the stalks of wine glasses, &c.

Sulphur also can be combined with arsenic, as with the metals; and the compound is more fusible than arsenic alone. The fusibility is increased by increasing the quantity of the sulphur; and the colour is yellow, orange, or deep red. It is called *yellow arsenic*, and *orpiment*, the (*sandarac* of the ancients) and *realgar*. The dangerous powers of the arsenic are considerably abated in these compounds. Hence it is that the Chinese, and other Orientals, form realgar into medical cups; and employ as a purgative, lemon*juice which has stood some hours in them. The sulphur can be separated again by sublimating the compound with potash, and by other processes.

Arsenic can easily be united with the metals in their metallic form, but only when it is itself metallized. The common way is to mix it with materials that will metallize it, and apply this mixture to the metal, with a proper heat, in the form of vapour. It whitens them, and makes them brittle. One of the distinguishing qualities of arsenic is that of uniting, when heated in any inflammable mixture, with some of those substances, and flying off with it. Hence it is reckoned a purger or purifier of glass; and is a powerful calciner, or scorifier of the metals. But it is no less hurtful, on the other hand, in metallurgy, by carrying the metals off with it; to prevent which is one of the great operations upon the ores in metallurgy.

Origin, or Natural State of Arsenic.

Arsenic is sometimes found pure, or in the form of solid metallic arsenic, but oftener more loosely concretioned, like a grey or black friable matter. But pure arsenic in any shape is rare; though, in the state of combination, there is plenty of it in many of the ores of metals, especially those of cobalt, copper, sil-

ver, and iron. In the white pyrites, it is known by the garlic smell when struck. It is most plentiful in this mineral, and in the ore of cobalt. Existing in so many compounds, from which it may be expelled by heat, it abounds in volcanic countries. In Solfatara, it contaminates every volatile subterraneous production, and is found in many of those forms into which we bring it in the operations of our laboratories.

There are also natural compounds of arsenic and sulphur, called *orpiment* and *zarnic*; but the greatest part of the orpiment in the shops is artificial. Arsenic for the use of the arts is prepared chiefly from cobalt ores and white pyrites, in Saxony, as a secondary business only, in the manufacture of zaffre and smalt. The arsenical fumes are collected in chambers, which act as subliming vessels, as we shall see presently. It is useful in the manufacture of glass, and in dying. Such, therefore, is the history of arsenic, considered as an object of chemistry.

The knowledge of this mineral is necessary to the physician, both on account of its great efficacy in the cure of some diseases, when it is properly used, and also on account of its noxious powers, in consequence of which, it is sometimes given with the most criminal intentions. In such cases, the physician is called in to assist in forming a judgment whether arsenic has actually been given or not.

It has long been one of the secret remedies employed by some empirical practitioners,...externally, for the cure of cancers, and other obstinate ulcers; and internally, for the cure of intermittent and other fevers. And the ancient physicians, in some of their prescriptions, employed some of the natural compounds of arsenic and sulphur. In later times, the first example of its being publicly recommended as a remedy for the cure of fevers, is in the *Memoirs of the Academy at Mentz*, for the year 1757, by a Dr. Jacobi. But we are most indebted to Dr. Fowler for his late accurate trials of it. They were conducted in the most judicious manner, to secure exactness in the dose, and to ascertain the efficacy of the medicine; and they are related so fully and circumstantially, that they give complete information and satisfaction, with respect to every particular that is most inter-

esting in the use of this powerful remedy. A better plan cannot be contrived for ascertaining the powers and uses of the medicines we employ.

Physicians and surgeons are sometimes called upon, in cases of supposed murder by arsenic, to give their opinion: and the questions commonly put to them are these:

1. Whether the appearances or symptoms observed in the dying and dead person give reason to conclude that they were killed with arsenic?

2. Whether certain drugs or powders which were given to the dead person, or mixed with his food, and a part of which are committed to the physician to be examined, be arsenic, or contain arsenic?

It is necessary to be cautious in giving our answer to the first question, which seldom admits of a perfectly decisive answer, if the presumption of poison rests on the symptoms alone; the symptoms produced by arsenic being not unlike those which appear in some diseases, such as the cholera. But these symptoms may add to the proof which may arise from other evidence.

The symptoms produced by a dangerous dose of arsenic begin to appear in a quarter of an hour, or not much longer, after it is taken. First, sickness, and great distress at the stomach, soon followed by thirst, and burning heat in the bowels. Then come on violent vomiting, and severe colic pains, and excessive and painful purging. This brings on faintings, with cold sweats, and other signs of great debility. To this succeed painful cramps, and contractions of the legs and thighs, and extreme weakness, and death.

After death, the intestines are found inflamed and corroded. And sometimes inflammations and erosions of the anus happen before death.

In examining the dead body, we must take care that we be not deceived by the dissolution of the stomach by the gastric liquor, and account it an indication of arsenic.

If we actually find arsenic in the stomach or intestines, or in the drugs or other suspected matters which were given to the dead person, we can give a decisive answer to these two ques-

tions. But we must make ourselves sure that what we judge to be arsenic be really so.

We must, therefore, take care to be well acquainted with the qualities of arsenic, by which it is distinguishable from all other substances. And its distinctive properties are these :

1mo, It is a heavy substance, which may therefore be separated by skilful elutriation from animal or vegetable matter, with which it may happen to be mixed in the bowels or in the drugs. Elutriation is commonly performed with water ; but if the arsenic is mixed with oily or resinous drugs, it may be performed with alcohol. In examining the dead body, therefore, it may be proper to wash out the whole contents of the stomach and bowels into a bason of water, and then, by careful elutriation, to try if any arsenic can be found in them. And in examining the drugs, if they be a mixture of different ingredients, we must dilute or dissolve them, by grinding them a little with water or spirits, and then elutriate.

2do, Arsenic, besides being a heavy substance, is volatile. When heated on a red hot iron, it evaporates totally before it be red hot, and goes off in white smoke.

3tio, It is easily metallized by mixing it with three times its weight of the black flux, and heating the mixture in a tube.

4to, In this metallized state, it easily penetrates copper, when assisted by heat, and gives to the copper a whitish colour like that of lead or tin. It must be made of a dull red heat. This will completely dissipate corrosive sublimate, or other things which can whiten copper.

5to, In its metallized state, if it be suddenly heated to a sufficient degree on a red hot iron, it takes fire, and burns with a flame, from which arises a smoke, which is white arsenic. Or, if the iron be not sufficiently hot to make it take fire, it simply evaporates, and gives vapours which have an odour like that of garlic. The same odour is perceived, if we mix white arsenic with an equal weight of charcoal dust, and throw a little of the mixture on a burning coal, or on iron strongly heated, so as to set the charcoal dust on fire. This experiment has been often misunderstood.

Having had occasion some time ago to exercise myself in these experiments, and to try with how small a quantity of arsenic they might be made, I found I was able, by means of a small tube, to get metallized arsenic from one grain weight of white arsenic: and with this metallized arsenic I made the other experiments.

Remedies to save, if possible, the life of a person who has taken Arsenic.

The first symptoms which the arsenic produces shew plainly that for some time after it is taken, it acts on the stomach and intestines, as an highly irritating, inflammatory, corrosive substance. But if the patient survive the first violent effects, the poison being evacuated out of the bowels, the symptoms which appear afterwards are those of excessive debility, and a great irritability of the intestinal canal, and of the whole system. The degree of debility is particularly remarkable. It is evident not only from the languor, distress, and feebleness of the patient, but also from the state of the pulse. I never felt a more feeble pulse than that of a person in this situation. All this is attended with a sort of paralytic affection of the limbs, and a degree of marasmus.

The methods commonly recommended to save the life of the person in the first of these states is, to give plenty of milk and oil, as obtunding remedies, and which help to wash and carry off the arsenic out of the intestines, while vomiting and purging continue.

A better practice, however, might be substituted for this. Arsenic being a heavy substance, is not easily washed out by milk: and it may probably coagulate the milk by its acidity. Oil will not mix with it after it is wet. I should prefer mucilage, taken in large quantities: and if it do not pass off quickly, I would promote its passage by means of a purgative, such as Glauber's salt, or sal catharticus amarus. A friend of mine once gave whites of eggs with success.

In the second stage of the disorders produced by arsenic, which is commonly of long duration, a mild diet of milk

is proper. The frequent use of opiates, to relieve from constant distress, and after some time electricity, are very serviceable. De Haen found electricity one of the best remedies for the cure of the disorders occasioned by lead. Mineral waters have been recommended, especially the sulphurous waters: and to imitate these, hepar sulphuris dissolved in water may be employed. But this practice is founded upon project and speculation, not upon experience.

METALLURGY.

THE nature of arsenic being now explained, you are prepared to understand the operations by which metals are extracted from their ores.

The first of these operations is to separate the ore as much as possible from the spar, or other stony matter that accompanies it.

When the ore is found in the vein in large masses, or fills up the whole, or a considerable part of it, many feet wide, which is often the case, it may be cut out tolerably clean, or free from the adhering matrix: or, after it is taken out of the vein, any part of the matrix that adheres to it, may be struck off. But, in many mineral veins, the ore is interspersed through the matrix in very small masses, and so entangled in it, that they cannot be separated in this way.

The expedient to which the metallurgists have recourse in this case, is, to take advantage of the great difference of specific gravity between the ore and the stony or earthy matter in which it is involved. They break or bruise the whole into small fragments, like gravel or sand, and then expose it, upon a board or shallow trough, to the action of a small stream of water running over it with moderate velocity, while the broken ore is gently stirred at the same time. The moving water carries along, and washes away the earthy and stony particles before it can move the heavier particles of the ore. This is called *washing*, or *dressing* the ore: in Latin, *elutriatio*. There are many ingenious and simple ways of performing this process, of which you will find a distinct account in *Agricola De re metallica*. This pro-

cess is easy, when the ore is found in sand or earth, which is often the case with regard to some metals. But others are, in general, found in a solid matrix, not divisible by water alone, or diffusible in it. It must therefore be divided, or broken down mechanically. This is done, in some cases, by flat iron mallets, or by means of stamping mills. It often happens, too, that the matrix is much harder than the ore, and then mechanical pulverization alone will not answer. This difficulty can often be obviated, by burning or calcining the mineral with a brisk fire of short continuance, and throwing water on it while red hot. The effect of this upon the stone or matrix is great, if it be calcareous or sparry, but less, yet very considerable, even upon quartz. Thus, therefore, this sort of ore, in a reduced state, can be pulverized and dressed with success. But, although the skill and address with which this art is practised enables the miners, in many cases, to separate the ore from very great quantities of the stony matter, some ores cannot be powdered and washed without loss of some of the metal: and, where circumstances are unfavourable, a great quantity is lost, in consequence of its being broken so small that the water carries it away. Therefore, in such cases, it is found more expedient to procure the separation by bringing the whole into fusion. This is much practised in Germany, in the management of some ores, but very little, if at all, in this country. They perform the fusion in the ordinary furnace, and mix the ore and stones of different kinds. When the whole is thus hastily melted, the ore, as it consists of metallic substances and sulphur or arsenic in an uncalcined state separates from the melted earthy matter, and is collected at the bottom. It also undergoes some change by this hasty fusion. Some of the sulphur and arsenic is dissipated; and some of the more calcinable metals are calcined and mixed with the scoriæ. But it still retains so much of its impurities, that it may be considered only as a sort of ore. This operation is called *crude melting*, or *crude fusion*. It is not for all sorts of ore, but only for those which are entangled with the matrix, so as not to be conveniently separable by washing, but capable of perfect fusion by proper additions.

When the ore is freed from all the earthy matter, which can by this or the former operation be separated from it, the next set of operations which it undergoes, are intended for separating the sulphur, or arsenic, or both, if it contain them. It is necessary to separate these with milder heat, and the action of air, before it be melted, on account of their strong adhesion, and their occasioning much loss of the metal, by carrying some of it off in vapours, and also occasioning more to calcine and mix with the scoriæ. The ore is, therefore, first exposed to the action of a gentler red heat, long continued, which is called *roasting* of it (*ustulatio*), most commonly in heaps, with fuel intermixed, in the same manner as bricks are burned. Sometimes this is done in a furnace of a particular structure, contrived with great ingenuity, for collecting and preserving the arsenic, and even some volatile and very calcinable metals, contained in the ores of that metal for which the whole process is chiefly carried on.

Some ores require several repetitions of this process of ustulation before they are sufficiently freed from volatile matters.

When these operations are finished, the metal remains more or less calcined, and therefore requires, in the next place, that the operation of *reduction* be performed. This is done in particular furnaces, of different structures, according to the degree of heat necessary, and the mode in different places. A considerable variety are described by Agricola, from which those at present in use do not differ essentially, except in the very large size, to which some are now carried. In these, the ore is melted in contact with the fuel, that the whole of the oxygen and sulphur, still combined with the metal, may be absorbed by the burning fuel, and carried off in the form of carbonic acid and sulphurous acid. Proper fluxes are also added for any earthy matters that still remain: and also earths, and even metals, are sometimes added, which still more completely absorb the sulphur. The desired metal, thus freed from extraneous matters, collects at the bottom, and the earthy and sulphurated matter floats above as a scum or slag. This is let off, in some cases, by a tap-hole, at some distance from the bottom. In other cases, it is drawn off with rakes, or driven off by the bellows. The melted metal is then

let out by a lower tap-hole, in the great furnaces, or lifted out of the small furnaces with ladles. The slag is, in many cases, rich in some other metal, which has been scorified in this process for the principal metal, and is worked off for it in other furnaces.

The next operation generally is *refining* the metals.

Many ores either do not require, or do not admit of all these operations, but agree best with the omission of some, and variation of others, as I shall observe more particularly hereafter.

In treating this subject, it is usual to mention the art of ASSAYING ores and metals, which is an assistant to the art of separating metals from their ores, and of refining them. The art of assaying is the art of performing all the operations I have been describing, upon small quantities of the subjects, and in a very short time, in order to judge of the nature of an ore, the metal it contains, the best manner of working it, and the profits it will yield. It is also necessary to the art of coining, and to the regulation of the fineness of plate.

The practice of this art requires the greatest degree of attention and accuracy in the artist, to avoid the smallest loss of any part of the subject he is working upon, by any mismanagement; as a small loss of this kind would occasion very great errors in the calculations of the profitableness of working the ore, or of the value of the subject of the assay.

To describe the art of assaying would require much more time than can be spared in an elementary course of chemistry. I must, therefore, refer you to those authors who treat it in the most judicious manner. I need scarcely name another, after mentioning Cramer's *Ars Docimastica*. He was a most excellent chemist: and his work is complete with respect to the *docimasia viâ siccâ*. Of late, however, another method of assaying, *viâ humidâ*, has been much cultivated. The best writers on this assay are Bergmann, Fordyce, and Woulfe. Mr. Fordyce was, I believe, the first who thought of this as a complete mode of assay. It certainly gives a more complete analysis than the dry way; but is too tedious for the necessary dispatch of business.

The dexterous use of the blowpipe is of unspeakable service in the examination of ores and minerals. By a proper application of the flame, we can either burn off all inflammable matter, or we can assist the substance on which it is directed to unite with, or act on the inflammable matter of the charcoal on which it lies. When we envelope the body in the blue point of the interior flame, the exterior flame keeps off the air, and allows the combination with the charcoal to take place, and to continue. But by directing the very point of the flame on the body, we consume all inflammable matter by the application of unsaturated air to it. Therefore, when we operate on metallic ores, we can, in an instant, either calcine or reduce the metallic part.

The operations of metallurgy, in the great way for commerce, are too various, and too complicated, to be described and explained in an elementary course of chemistry, and at any rate, cannot be introduced at present; because, since the propriety of them depends on the nature of the various metals contained in the ores, which is yet unknown to you, you could not understand the most perfect account of them. On this subject, which comprehends almost the whole of our science, you must consult the *Ars Metallica* of Agricola, and the *Metallurgy* of Schlutter. From this last work, which is a very excellent performance, Macquer has given very good extracts in the articles of his chemical dictionary.

The very short account which I have now given you of the art of metallurgy was a necessary preamble to the philosophical study of the different metals, considered as the subjects of chemical science. It was, I confess, somewhat irregular to include arsenic, one of their number, in this preamble; but so many of the metallurgic processes are performed in order to get rid of this troublesome ingredient, which is not sought for on its own account, nor was even thought metallic, till of late, that we could not proceed intelligibly without a certain knowledge of its peculiar qualities.

I shall now enter professedly on the investigation of the peculiar properties of the different metals, following, in each, the method of treatment already familiar to you: and I shall

conclude each article with a short account of its natural state, and the metallurgic processes for obtaining it in its purest metallic form;...processes which, although somewhat alike in all, must yet be modified, in compliance with the peculiarities in the chemical properties of each.

In prosecuting this important part of the course, which, with pharmacy, constituted almost the whole of ancient chemistry, I shall take the metals in that order in which I think their properties most easily explained. This is almost the same with that of their disposition to be calcined or burned, which are equivalent changes of their appearance and properties. Of all the metals, gold, or platinum, is the most tenacious of the metallic form: and, on the other hand, the most calcinable or combustible of them all, is the mineral called *manganese*, now found to be a metal, having singular properties, which are most curious in themselves, and are of great assistance to us in explaining and establishing some of the leading doctrines of chemistry.

For these reasons, manganese shall take the lead: and I shall consider the metals in the following order: magnesium, iron, mercury, antimony, zinc, bismuth, cobalt, niccolum, lead, tin, copper, silver, gold, and platinum. Having already considered arsenic, I now proceed to

GENUS II....MAGNESIUM.

THIS is by no means a rare production: and it has been long in our hands, and much employed, although its nature is but lately understood. It often occurs in our mines: few are altogether without it; and some contain very great quantities. Its common appearance is a hard substance, of a grey colour, and frequently of a chocolate colour, which may almost be called black. It is easily known by its soiling the hands excessively, like a dark brown greasy pigment. The Germans, for this reason, call it *braun stein*. It may be seen at every potter's kiln, where it is used for giving the black, or dark purple glazing to the very coarsest of our earthen ware. It is very abundant in Derbyshire, in a fossil called *black wad*; and was, for a while, sold for a

coarse pigment, till the knowledge of some of its remarkable properties put a stop to its employment in this way. For its other varieties, I refer you to Kirwan's or Cronstedt's *Mineralogy*. It is employed for tinging glass purple, and to compose the enamels that are used in decorating the glazing of some earthen ware, such as the tiles with which our chamber fire-places were formerly lined,... and indeed for the figures on much of the common kinds of Delft ware. It is also used for a purpose which seems the opposite to these, namely, for clearing glass of all colour, especially that green colour with which it is generally tainted.

The chemists knew nothing farther about manganese. They supposed it to be an ore of iron, but of a bad quality, because little or no iron is obtained from it. Some, however, have long suspected that it was a metallic calx, of a peculiar kind, and by such curious naturalists, it has been a good deal tortured. It has been described under various names,...*black wad* in England; *braun stein* among the German miners; in Latin it has been called *manganesium*, *magnesium*, *magnesia nigra*, &c. Chemists have now agreed to call it MAGNESIUM; and under this name I shall speak of it.

It is needless to mention the many vague and random experiments which were made on it during the nonage of chemical science. We never had any clear notion of its properties, till Dr. Scheele took it in charge: and he has given an account of his examination in an admirable paper, read to the Royal Academy at Upsal, and printed in the Transactions, in the Swedish language, from which it was soon translated into German, and thence into French, and here into English. Whatever is the subject of Scheele's examination, he shews in his investigation such an uncommon degree of industry, of ingenuity, and of chemical skill, that you cannot have a better pattern for the proper conduct of chemical researches. I have often quoted this excellent author, and shall yet often refer you to his ingenious dissertations. To him, as I have said, we owe our first clear knowledge of this mineral. But it was Dr. Gahn, another chemist of the same academy, who first demonstrated magnesium to be a metal, by reducing it completely to the state of a hard and brilliant metal, by

treating it properly with charcoal in a most violent and long continued heat.

Magnesium has no volatility in its natural state. But, if exposed for a long time to a red heat, it suffers a considerable loss of weight. If this be done in a proper apparatus, we obtain from it a prodigious quantity of aerial matter. This, when examined, is found to be vital air, of the purest kind,...when the magnesium itself is pure, which, however, is rarely the case. It is frequently tainted with iron, and with arsenic, and with earthy matters. Carbonic acid, therefore, often taints the aerial product. Many chemists affirm also, that the purest manganese always emits azotic gas in the beginning of the experiment; and that a stronger heat is necessary for detaching the vital air. This, however, is its most abundant product: and it is at present the substance from which it is obtained for most of our experiments, and also for most important purposes in the arts.

This effect of heat on magnesium induces us to consider it as a metallic oxyd, similar to many others very familiar to the chemist; but it differs from them in a remarkable circumstance. When this great quantity of vital air has been obtained from it, the remainder is of a much brighter colour than before: and in some cases, in which we have expelled the greatest quantity possible, it becomes perfectly white. The oxyds of other metals are always of the deepest colour when the greatest quantity of oxygen has been taken from them.

When magnesium has been thus deprived of some oxygen, it speedily recovers it again, merely by exposing it to the common air. The rapidity with which it attracts the oxygen of the atmosphere, is indeed very remarkable. A few hours will sometimes suffice for restoring it to its former state of repletion with oxygen: and in thus recovering its natural share, it also recovers its natural colour, and becomes black as before.

When oxygen, already in a gaseous form, is made to combine with other matter, there is always an extrication of heat and light. The present case is no exception, when circumstances are favourable. When a considerable quantity of magnesium, which has been deprived of its abundant oxygen, is exposed to the air in an extensive surface, it recovers it with

heat, and even incandescence. It cannot flame, because it is not volatile.

This surprising property of magnesium occurred to Dr. Scheele in the course of his examination. Having exposed a quantity of black magnesium to a red heat for a quarter of an hour in a phial, the mouth of which was stopped with a piece of chalk, he turned it out, still white on a piece of paper. It soon deflagrated, and became black. If it was kept shut up till quite cold, and then turned out on a hot plate, it immediately became red hot. It does so in an instant, if loosely poured into a jar containing vital air; and may be seen white, as it enters this air, and black before it reach the bottom, when the jar is tall.

These and other analogous phenomena made Dr. Scheele suppose that black manganese was a substance which had attracted phlogiston. And this opinion, natural to a chemical philosopher of that day, was confirmed by a series of the most curious experiments, made by treating magnesium with the more active chemical substances. Of these the acids afford the most instructive phenomena, which I shall take pretty much in the order in which they occurred to Dr. Scheele, led by the train of his speculations and conjectures, presuming that the procedure of such a mind will not be unpleasant to you.

Magnesium, in its natural black state, dissolves in the acids but slowly, and with difficulty: and in some it does not dissolve at all. I lately had occasion to remark, that the metals, when very much calcined, that is, when combined with a great quantity of oxygen, have their attraction for acids greatly diminished: and there are several examples of their being thereby rendered altogether insoluble. Manganese in its natural state is similar to those oxyds. But if some vital air be expelled from it by heat, or if it be taken in its white state, it will be dissolved in such as did not act on it in its black state.

The sulphuric acid is altogether inactive on it in its natural state. But if it be treated with charcoal, and made by heat to give out a prodigious quantity of carbonic acid,....and if it be then put into sulphuric acid, it dissolves very readily. It is pretty much the same with respect to the other acids. If strong sulphuric acid be boiled for some time on black manganese, a

small portion is dissolved, the acid having expelled some oxygen by the assistance of the great heat.

If precipitated by a caustic alkali from any of those solutions, it is always white, or at least, is far from its ordinary dark colour :....and in this state it dissolves readily in all the acids.

These facts make it clear that the solubility of magnesium in the perfect mineral acids depends greatly on its degree of oxydation. It is insoluble when the oxygen is abundant, but soluble when this is diminished to a certain degree. What proportion of the abundant oxygen must be abstracted, has not yet been ascertained with precision. It appears also, that charcoal has a greater attraction than magnesium for oxygen,....at least when its attraction is aided by the volatility of oxygen augmented by heat. But there are some other circumstances in the relation of magnesium to the acids, which are not a little mysterious and puzzling. Although the sulphuric acid does not dissolve manganese, the sulphurous acid dissolves a part of it very readily :....yet the salt is not of the kind we expect from such ingredients ;....it is a permanent sulphat of magnesium :....and if we precipitate the magnesium by an alkali, it is in its deoxydated state. Therefore the acid in it is not the sulphurous but the sulphuric, having its full share of oxygen.

Perhaps this phenomenon explains the solubility. The black manganese may be supposed to have a portion of its oxygen redundant, while the sulphurous acid is deficient in oxygen. The attractions may be supposed nearly equal ; so that when the acid has taken as much of the redundant oxygen as completes it to the state of sulphuric acid, this acid dissolves what part of the manganese has been so much deoxydated as to become soluble. This explanation is rendered very probable by the subsequent experiments of Dr. Scheele.

An ounce of aquafortis and twenty grains of manganese being mixed, no solution follows. But upon adding about a drachm of vinous spirits, and making the mixture lukewarm, there is an effervescence and eruption of nitrous gas ;...and the manganese now dissolves completely : and after this, four additions, of twenty grains each, will be dissolved. The mixture grows very hot. I imagine that the effervescence is chiefly produced

by the carbon of the alcohol, and partly perhaps by the oxygen gas or vital air.

Dr. Sheele effected the solution of manganese in nitric acid in different ways,...by means of sugar, or essential oil, &c. But a much more curious means occurred to him. He, and indeed other chemists before him, had noticed the remarkable effect of the sun's light, in blackening the vitriolic acid, and in causing the pale nitric acid to become ruddy and fuming: and they attributed this to the introduction of phlogiston, because sulphur was produced, and because sugar produced the ruddy fumes. Observing that sugar enabled the nitric acid to dissolve manganese, he tried whether the same effect might not be also produced by the sun's light. Pouring half an ounce of nitric acid on twenty grains of manganese, and agitating the mixture, it continued quite inactive. He then set the matrass in the strong light of the sun, on midsummer day: and in an hour's time, he had a perfect solution. He added twenty grains more, which were also dissolved,...and continued adding till no more was taken up. He precipitated the manganese by means of a diluted solution of potash: it was perfectly white. He considered it as manganese united with phlogiston and fixed air. He mixed it with one-fourth part of nitre, and gave it a red heat in a retort, and obtained a quantity of nitrous gas. The nitre in the retort was alkalized.

Reflecting on these experiments, shewing the solubility of manganese in pale nitric acid by means of inflammable bodies or light, we have reason to conclude, that these bodies act first on the nitric acid, producing their usual effects, viz. abstracting or expelling a part of its oxygen, and changing it into a more volatile acid. It then becomes a solvent for the manganese.

But in whatever way we dissolve it, we always find it in a de-oxygenated or white state, when we precipitate it with an alkali; and in this state it will dissolve without difficulty, if done soon,... but if allowed to remain some days, it becomes black and insoluble.

I have called a portion of the oxygen combined with manganese *redundant*. It is unquestionably provided with it, to the

very point of saturation; and what has been last accumulated seems to be weakly united: for it is easily abstracted from it by other bodies,....particularly by some inflammable substances. Of this we have a remarkable example, by mixing a quantity of black wad in powder, with as much boiled lintseed oil as will just make it stick together in clots. If this mixture be made up into a heap, and set in a warm place, as on the hearth, before a glowing fire, so as to become lukewarm, it will take fire in about half an hour; and it deserves remark, that this combustion is accompanied by a smell by no means offensive, though very strong. It is somewhat aromatic, and altogether unlike the smell of lintseed oil burning with a smothered heat. I imagine that the redundant oxygen is combined with the oil, which we know to have a considerable attraction for it, and to absorb a great deal from the atmosphere. This combination is accompanied by the extrication of heat in the same manner as in the mixture of nitric acid with such oils. Only, the oxygen of the magnesium is probably neither so copious nor so loose as in the nitric acid. During this combustion, the carbon and hydrogen of the oil fly off with the oxygen of the manganese, forming carbonic acid and water. And the manganese soon recovers its abundant share of oxygen again, by exposition to the atmosphere.

The mixtures of manganese with muriatic acid exhibits phenomena still more remarkable, and indeed is one of the most curious facts in chemistry. When the common muriatic acid is applied to black manganese, it dissolves it, slowly indeed, but easily, and in considerable quantity, and needs no addition of inflammable matter. But it adheres so feebly, that even water suffices for precipitating the greatest part of it, in its ordinary form. This easy solution made Dr. Scheele suspect that muriatic acid, in its ordinary state, contained some phlogiston, naturally combined with it, which reduced the manganese to a less calcined state, and thus disposed it to dissolve so easily in the acid. This conjecture was confirmed by the phenomena which the mixture presented when a gentle heat was applied to it. He learned that a part of the acid is greatly changed from its ordinary state, and is gradually converted into a penetrating va-

pour, of a yellow colour, and most insupportable suffocating smell.

This gas is one of the remarkable objects in chemistry. It is with difficulty obtained in any other form than that of an elastic aerial matter, having scarcely any attraction for water. The ordinary muriatic acid gas has a strong attraction for water, and is, by this means, obtained in the ordinary form of a watery acid: but when distilled from black manganese, it will scarcely unite with water, and unites only in very small quantity, and is easily separated again, or rather is with great difficulty preserved in a combined state. A freezing cold, indeed, will condense it into a sort of soft or solid matter, but when the cold abates, it immediately reassumes the gaseous form. It may, however, be condensed, in consequence of its attraction for other substances, such as the alkaline salts, and especially the inflammable substances, such as oils, animal and vegetable substances, some bitumens, and metals in their metallic state. It acts so strongly on many of those substances as to inflame them. Thus phosphorus, plunged into this gas, takes fire immediately. Sulphur also, if hot enough to begin to melt, instantly takes fire. Even charcoal, if in exceeding fine powder (such as may be obtained by washing the nitre out of gunpowder) when made warm, and thrown loosely into this gas, instantly kindles. I have met with some assertions that the vapour of alcohol also takes fire in it: but I have not found it so, either with the vapours of alcohol, or that of the vitriolic æther. Nor have I found that it kindles some of those compound hydrogenous gases which are so ready to take fire. The abominably fœtid gas, containing phosphorus and hydrogen, fires pretty readily in this muriatic gas, but requires particular management, and a particular state of the ingredients, which you will understand as we proceed.

Most of these curious facts occurred to Dr. Scheele, although in a more complex manner, because he was not thoroughly instructed in the nature of this vapour. But he saw enough to make him conclude that the muriatic acid, in the state of a yellow vapour, is deprived of a part at least of the phlogiston which he supposed it to contain when in its ordinary state. He also found reason to conclude that it has a strong disposition to

reunite itself to that principle ; and in consequence of this attraction, it acts on bodies which contain it,...and this with great vivacity, when they hold it in abundance, and but loosely combined. He accounts in the same way for its action on the metals, by which it is eminently distinguished from the common muriatic acid, which, as I have told you, acts on them in a languid manner, if in their metallic form, though it dissolves their calces very readily,...more readily indeed than the other acids.

Induced by all these facts, Dr. Scheele called this vapour or gas the *dephlogisticated muriatic acid*. We need not wonder that he employed this language, and viewed the phenomena in this light ; for, when he made and published his examination of manganese, the phlogiston was every where admitted as a principle in chemistry : and Dr. Scheele was the very first that expressed any dissatisfaction with the simple form in which this doctrine was delivered by Dr. Stahl. I have already had occasion to mention the ingenious and fanciful modifications of the original doctrine of Stahl, which this excellent chemist attempted to establish, but which he would have been the first to abandon, had he pushed some of his own experiments one step farther. I hold it, therefore, to be unpardonable arrogance in the French chemists to say that no man can entertain the belief of the existence of phlogiston who has a grain of common sense. Scheele's dissertations, of every kind, will ever stand in the first very rank of chemical writings. By the natural progress of all knowledge that is founded on experiment, we have come to interpret the many discoveries of Dr. Scheele in a different way. But the discoveries remain the same ; and they are his, and resulted from deep and ingenious meditation. He considered all the phenomena which we derive from the privation or absence of oxygen as proceeding from the addition or presence of phlogiston : and he ascribed to the abstraction of phlogiston what we know to be owing to the acquisition of oxygen.

Since the time of Dr. Scheele, all these phenomena of the muriatic acid and manganese have been maturely considered, carefully investigated, and clearly explained, principally by the chemists of France. We now hold that the change of ap-

pearance and properties which the muriatic acid suffers, depends on the addition to it of a great quantity of oxygen, which it acquires from the manganese. For this reason, the muriatic vapour, which I am now considering, has acquired the name of OXYGENATED MURIATIC ACID. Mr. Kiiwan calls it the OXY-MURIATIC ACID. You certainly recollect, that I have several times had occasion to mention a particular state of this acid in which it was surcharged with oxygen; and in consequence of this redundancy, had some singular properties. It was thus that I explained the process for preparing muriatic æther by means of the smoking liquor of Libavius, and several experiments of Berthollet, establishing the constitution of volatile alkali, with other things of similar nature. It was this preparation which I then had in my thoughts.

We have proof that the acid, in Dr. Scheele's experiment of distilling it from manganese, has abstracted oxygen from that mineral. Filtrate what remains in the retort, and add a very pure fixed alkali,...the manganese is precipitated in the form of a white powder or mud; a sure sign of its having lost some of its oxygen. If the precipitate be hastily washed and dried, and then urged by a strong heat, in a proper apparatus, we may perhaps still obtain some oxygen, by the extreme force of heat; but the quantity will be exceedingly small.

I shall now repeat, in a more comprehensible and instructive manner, what I formerly mentioned when I gave you an example of the manner in which the French chemists extended the doctrine of Lavoisier to almost every chemical phenomenon in this world; namely, their account of the constitution and formation of the volatile alkali. When the pure or caustic alkaline gas is made to mix with the oxy-muriatic gas, there is an immediate decomposition of both. The redundant oxygen of the latter seizes on the hydrogen of the volatile alkali, and forms water; the azotic gas is set at liberty; and the oxy-muriatic gas is changed into common muriatic acid, by the departure of the redundant oxygen. If we have made use of a watery solution of the caustic volatile alkali, and make the oxy-muriatic gas pass through it, we have an effervescence, occasioned by the extrication of the azotic gas. All this was discovered by Dr. Scheele, and is related in his Essays.

Some of the French chemists, and particularly Mr. Berthollet, the most eminent of them, have followed Dr. Scheele in the investigation of the properties of this remarkable gas; and have made some very curious and important discoveries relating to it.

I shall briefly mention some of its leading properties, referring you for farther information to Mr. Berthollet's most excellent dissertation, *Observations sur quelques combinaisons de l'Acide Marin dephlogistiqué, ou de l'acide muriatique oxygéné*. It is one of the best pieces of experimental philosophy that has appeared in any language.

1. The oxy-muriatic gas retains its affinity for alkalis; but wonderfully diminished, and modified by very particular circumstances. It unites, he says, with mild alkalis without effervescence. I have not yet examined this with sufficient care, but am disposed to doubt it. It is scarcely possible to procure an alkali perfectly saturated with carbonic acid. I never saw potash that was so but once. This gas contains so little saline matter, and its attraction is so weak, that it must of necessity attach itself in preference to such of the alkali as is in a caustic state; and I apprehend that this may have been enough to absorb the whole. The vast quantity of water also, that is necessary for condensing the gas, may absorb a great part of the carbonic acid that is really detached from the alkali: and the fact is, that heat applied to this mixture will detach much carbonic acid from it.

2. When the oxy-muriatic gas was condensed by a very diluted solution of caustic potash, the alkali became turbid, and deposited some earth, and some saline crystals. The mixture being evaporated by a most gentle sand heat, afforded two salts,....namely, the ordinary salt of Sylvius, and another, easily separable from that salt, because it dissolves much more copiously in hot than in cold water. When the process is well performed, we obtain about four parts of salt of Sylvius and one of this new salt.

3. This salt has many singular properties. Its crystals are hexaedral prisms, or more frequently confused laminae. It has an unpleasant maukish taste; and raises a feeling of coolness on the tongue, as nitre does. It contains the acid in its highly oxygenated state. An hundred grains of the dry

salt yield 75 cubic inches of vital air by means of heat, and yield it more easily than nitre does. Mr. Berthollet, observing the vital air so copious in it, and so loosely combined, mixed it with charcoal, and tried whether this would detach it by the assistance of heat. It deflagrated with prodigious violence: and the acid was not destroyed, but only reduced to its ordinary form; for the residuum was the ordinary salt of Sylvius. Therefore no oxygen had operated in this detonation, except the portion obtained from the manganese. Mr. Lavoisier found that 100 grains of the salt contains 37 of oxygen, which requires 14 of carbon to separate it, and produces 51 cubic inches of carbonic acid.

4. Mr. Berthollet, from these and other analogous experiments, infers that all the oxygen which produced that change in the marine acid is concentrated in this salt; and that it contains no other, nor any acid in its ordinary state. He therefore calls it the OXYGENATED MURIAT of potash or of soda. One part of this salt contains all the redundant oxygen that is furnished by six of oxy-muriatic acid. I may remark that the nitrose acid, in its union with alkali, exhibits phenomena pretty similar. We obtain a true nitre, and a nitrous gas.

The union of the ingredients of this oxy-muriat seems very slight. Exposition to the air seems to decompose the acid: for in a few days, or even hours, the salt changes to the ordinary salt of Sylvius. This decomposition happens more speedily in a watery solution of the salt: and we see a continual simmering on its surface, by the escape of minute bubbles of elastic matter. This is increased by exposure to the rays of the sun, so as to be like an effervescence. This is vital air, of the purest kind. It would seem that the caustic alkali acts too powerfully on the basis of the ordinary muriatic acid, and thus diminishes its attraction for the oxygen; or the oxygen exists in it, perhaps, in a semi-elastic state. Mr. Berthollet also thinks that the vast abundance of water necessary for absorbing this gas prevents a closer union of the acid and alkali. He found that the combination could not be effected unless the solution of the alkaline salt be extremely diluted. If this liquor be evaporated, preserving it at the same time from the action of light, or the naked fire

it undergoes, at a particular period of the evaporation, a sudden change, by which the above salt is formed; and after this, neither the liquor, nor any of the salts which it affords by evaporation, are possessed of the peculiar powers of the oxy-muriats.

Dr. Scheele discovered in this oxygenated acid another most remarkable property, namely, a power to destroy all vegetable and animal colours, and even those which are most permanent, prepared for the purposes of dyeing. It whitened or bleached vegetable substances in a surprising manner. Mr. Berthollet first thought of applying it to this use; and found that bees wax, brown linen yarn, and cloth, are bleached by it in a few hours or minutes, as effectually, and with as much safety to the staple of the goods, as if they had been exposed to the sun and air, with that intention, for as many weeks.

In consequence of this great discovery, trials have been made, with a view to the employing it in the art of bleaching fine linen, or cotton cloths, threads, and light manufactured goods. Mr. Berthollet has published the process, as it has been practised in some manufactories in France; and his account of it is translated into our language*.

The first trial of it in the great way, however, was (according to the best of my information) made in Scotland, with the assistance, and under the direction of Mr. Watt, who

* Therefore I need only mention here, that Mr. Berthollet produces the oxygenated vapour of muriatic acid, or oxygenates the acid, during its formation. He mixes, in dry powder, six ounces of black manganese with 16 of common salt. A tubulated distilling vessel is prepared, whose pipe is inserted into a receiver with two necks; and into the opposite neck is inserted the pipe which conveys the gas into the vessel containing the liquor which is to absorb it, or the matters which are to be bleached by it. This powder is put into the retort; and then there is poured on it 12 ounces of strong sulphuric acid, diluted with nearly as much water; and the stopper is put in. Gas is immediately produced in vast abundance, and passes into the rest of the apparatus. The two-necked receiver condenses the ordinary muriatic acid; but the oxygenated gas passes on to the absorbing vessel. No heat is applied till the emission of vapour becomes very gentle. The heat is cautiously and slowly raised to boiling, and continued till the two-necked receiver grows hot. This finishes the distillation. The absorption is promoted by churning vanes, which are worked by some machinery. Thus the absorbing liquor is more speedily and thoroughly impregnated. (*Annales de Chimie, t. ii.*)

had been at Paris, and had conversed with Mr. Berthollet, and immediately formed the design to try if the powers of this acid could be employed in practice ; for Mr. Berthollet had only considered it as a project in speculation. Mr. Watt had an opportunity soon after to make his experiments in the bleachfield of a friend at Glasgow : and since that time, the process has been applied to this purpose in many other bleachfields. It is best adapted, however, to the bleaching of thin goods, such as lawns, and fine muslins, and fine thread, and stockings. These require less of the acid than coarser goods, the thick and harsh threads and fibres of which are penetrated with difficulty, and also contain much colouring matter, which soon exhausts the strength of the gas. Attempts have also been made to bleach rags for paper. The methods employed are frequently to wet the matter to be bleached, by dipping it into water, while it is at the same time exposed to the vapour of the acid ; or water which has been made to absorb some of the vapour is applied to it ; or it is steeped in a solution of fixed alkali, or in lime-water, which has absorbed some of the vapour. Such solutions are found to have the bleaching power, although the acid be saturated with alkali.

Different methods are employed by different manufacturers, according to their notions of their respective efficacy : and each manufacturer has his nostrum, which is a secret. At present, none of them, I believe, use the simple oxygenated acid, which was formerly prepared for them, as a steep. The smell which it occasions is abominable, and cannot be cleared from the hands for many days. The workmen therefore will not submit to it. They either use the vapour procured by Berthollet's process, with alternate dippings into water,.... the whole of which operation is performed in a close chamber by the intervention of machinery ; or, more commonly, they employ solutions of alkali impregnated with the vapour. A chemist in Glasgow has made a great improvement upon the whole process by employing lime instead of alkali. He thereby prepares the drug in a very concentrated, and even a solid state.

Mr. Berthollet's trials to combine this volatile acid with fixed alkali have also produced some other surprising dis-

coveries. Observing how much the oxyd itself was disposed to give out its oxygen to inflammable substances, and how loosely it is combined in the acid over-charged with it, while this acid still retains its relation to alkalis, he tried the effect of the neutral salts produced by it. When the oxygenated muriat of potash is ground in a mortar with sulphur, small explosions happen under the pestle, which affect the hand of the operator like an electric shock. And if hastily ground, with strong pressure, the whole will explode. Nay, if the salt alone be thrown into sulphurous acid, it will explode.

Mr. Berthollet also examined, in the same way, the super-oxygenated muriat of soda. This deliquescent neutral salt gives out its abundant oxygen by mere exposition to the air, and changes to common sea-salt. When treated in close vessels, 100 grains yielded 75 cubic inches of vital air, of the greatest purity, with much less heat than nitre yields it. It was now a common muriat of soda.

He composed a gunpowder with the muriat of potash: and it was said to be vastly stronger than the nitrous gunpowder. Trials were made of it at Woolwich; and it was found that it was really stronger in small charges. But there was no sensible difference in great quantities; so that it was not thought worth while to prosecute the discovery further.*

Such gunpowder has qualities which make it inferior to the common. The very loose combination of this oxygen must cause the powder to become effete. The residuum of the detonation will be digestive salt, instead of the hepar sulphuris left by the ordinary powder. This will be more hurtful to the fire arms than fixed alkali. It would also appear, from the accident which happened in the preparation, that it is more disposed to explode in the operation of grinding.

From the whole of what I have said on this subject, it appears that the nature of the muriatic acid is very

* The oxy-muriats of lime, barytes, and strontites, deserve a trial for a fulminating composition.....EDITOR.

singular, when we compare it with the other two fossil acids.....These, when they have not the sufficient quantity of oxygen, are more volatile than ordinary. And their attraction for water is diminished. The muriatic acid, on the contrary, has its volatility increased, and its attraction for water diminished, by receiving enough of oxygen.

Dr. Scheele's experiments and reasonings have also shewn that there is a singularity in manganese, when we consider it as a metallic calx. It is most coloured, or darkest, when most calcined; and becomes white by abstraction of oxygen, contrary to other metallic calces. And it gives colour to its solutions, and to glass, when it is highly oxydated; but when this high degree of oxydation is abated, the colour disappears. The oxyds of other metals in general give most colour when they are least oxydated. This singularity in manganese is finely seen by treating a small portion of it with the blowpipe. A small bit of the *sal microcosmicus* being melted on charcoal by the blowpipe, if a minute portion of the black manganese be added, the globule acquires a red colour, so much the fuller, as we have added more of this oxyd. If we keep this globule in the middle or blue part of the flame, where it is defended from the action of the air, the red colour vanishes, by the reduction of the calx by the charcoal. If we now direct the point or exterior part of the flame to the under side of the globule, the effect of the charcoal is prevented, and the reduction already operated is destroyed, and the globule becomes red. We may thus change the colour as often as we please. The smallest particle of nitre being put to the colourless globule makes it red in an instant, by calcining the manganese.

A globule of manganese and borax preserves its dark red or black colour under this treatment, probably by keeping it from touching the charcoal.

We have an example of the colour it gives in its highly oxydated state, in a watery solution of a compound of manganese and fixed alkali, analogous to a *liquor silicum*. This combination is best formed by mixing the manganese with nitre, and giving the mixture a mild melting heat. The nitric acid is expelled by the heat, leaving the manganese well

stored with oxygen. The alkali remains combined with the manganese; and forms with it a dark green or blackish mass, which is soluble in water,...and gives it a green colour. We should perhaps account it a blue; because in a day or two a yellow powder falls down, and the solution is blue. The combination is but loose. Water separates it, first of a violet colour,...then red, which grows brown,...and lastly black. If sulphuric acid be added, to separate the alkali, the solution becomes colourless, the acid dissolving the deoxygenated manganese. Such a variety of colours have procured to this solution of nitre alkalized by manganese the name of *chamelion minerale*.

If we add a few drops of a solution of hepar sulphuris to the solution of manganese in the fixed alkali, it no longer exhibits the changes of colour. It produces this effect by its strong attraction for oxygen, by which it deprives the manganese of that precise quantity which enabled it to impart those colours.

It would appear that manganese clears glasses of the yellow and green colours which tinge them, by yielding a quantity of oxygen sufficient for calcining the colouring matters. When too much manganese is employed, after having discharged the colours produced by other metallic contaminations, it communicates its own colour,...a purple.*

Liquid phosphoric acid, as produced by the spontaneous decomposition of phosphorus without heat, dissolves manganese, giving a fluid of a rich red colour. If this be kept in a phial closely shut up, it loses its colour,...but resumes it by exposing the whole to the air in the process of filtration. This may be repeated as often as we please, and no matter is

* This property seems to me to have been longer known than is commonly supposed. Pliny says, "Mox, ut est astuta et ingeniosa solertia, non fuit contenta nitrum miscuisse. Cæptus addi et *magnes lapis*: quoniam in se *liquorem* vitri quoque ut ferrum trahere creditus." I think it probable that *magnes lapis* is manganese. The sentence has no truth, if the loadstone be meant; for this destroys all beauty in glass. Fossils were then little known: and Pliny was not a skilful fossilist,...*liquorem* may be a corruption for *colorem* or *livorem*. He is speaking of the perfection to which the manufacture had been brought; and says that the most valued was what was clear and colourless as crystal; and then he relates the above practice.

separated by the filtration. This is undoubtedly produced by abstraction of oxygen from manganese, and restoration of it by the atmosphere.

Acetous acid dissolves the black oxyd; and, in this state, very readily produces æther, when treated with alcohol. It also gives most beautiful crystals, when employed to dissolve copper.

Mr. Milner of Oxford published a paper in the 79th volume of the Philosophical Transactions, giving the general result of a number of experiments he had made with manganese, by making it red hot, in tubes of iron, or of earthen ware, and forcing the steam of water and of other things to pass over it, or through it: and among these, he tried the vapours of the pure or caustic volatile alkali. It always happened, that when the vapour of this alkali passed through the red hot manganese, it was partly converted into vapour of nitrous acid. This effect was constant. But he did not attempt to examine and ascertain how much of the nitrous acid might be produced from a limited and known quantity of the volatile alkali.

This remarkable and interesting experiment is easily explained by Mr. Cavendish's discoveries, and the new theories in chemistry to which they have given rise. He discovered that water is produced from inflammable air and vital air; and that nitrous acid can be produced from azotic gas (phlogisticated air) and vital air. Therefore, to understand Mr. Milner's experiments, since we know that the volatile alkali is a compound of hydrogen and azote, we need only suppose that part of it is totally decomposed and destroyed by the action of the oxygen contained in the manganese. Part of it, uniting with the hydrogen, forms water or watery vapour; and part, uniting with the azote, forms vapours of nitrous acid.

He observed also that the steam of water, passing through red hot manganese, promoted very much the extrication of those gases which it affords by heat.*

* There is a rumour that the French manufactured saltpetre during the late war, by obtaining nitrous acid from the vapours of volatile alkali, forced to pass through red hot manganese.

Having mentioned the most important properties of this remarkable substance, we should next consider the methods of reducing it to its metallic state. This has been but little studied; and its metallic properties are very imperfectly known. The reduction of manganese to a regulus is a very difficult process. This was first accomplished by Mr. Gahn of Sweden.

A crucible must be lined with wetted charcoal, (rendered very dense, and compacted by beating), leaving a small hollow in the centre, to receive a ball of the oxyd, made up with oil into a compact paste. Charcoal is put in above it, and well compacted by beating: and another crucible is luted on, also filled with charcoal. The most violent heat must be given for an hour and a half. A button is thus procured, of a dull iron colour, commonly rough on the surface. This arises from minute globules of manganese less perfectly reduced. It requires even more heat than iron for its fusion: and no chemist has been able to join pieces in this way. All saline fluxes are found hurtful to the operation.

The metal quickly calcines by exposure to the air, and is soon resolved into a black oxyd. To preserve specimens in a metallic state, it is necessary to varnish them; for even the air of a phial suffices for rusting it in a few hours. I have some suspicion that it absorbs azote as well as oxygen, for I observe that it leaves a smaller portion of that gas unabsorbed than any other process I have tried. 200 grains of regulus increased in weight 76 grains in the open air. Another 200, from the same mass, exposed in vital air, increased only 65.* The specific gravity of magnesium is about 6,35. It is quite brittle; and usually contains iron, which is not separated without extreme trouble.

* This conjecture of Dr. Black's is corroborated by the observation of Mr. Seguin, that black manganese yields azotic gas in low heats....EDITOR.

GENUS III....IRON.

AFTER manganese, we are now to consider iron.

I choose to describe iron next, and among the first of the metals, for many reasons. It is the most abundantly produced by nature. It is also by far the most useful among the metals and of the greatest importance, by having a combination of properties, which make it an excellent subject for the ingenuity and industry of man to work on. These properties are, a strong cohesion of its parts, by which it excels all the other metals: and which, in some states of the iron, is attended with great toughness and ductility; in others, with excessive hardness; and in others, with great elasticity.* In these different states, or intermediate ones, it is excellently adapted to different uses. We can also soften it by heat, and thus work it easily, under the hammer, or by the compression of rollers, into different forms: and when strongly heated, different pieces of it can be joined firmly together. We can also have it in a fusible state, and cast it in moulds.

Iron is singular among the metals, and indeed all other bodies in nature, by being the only one affected by the magnet. And as the magnet can be made to communicate to iron its own polarity, and other magnetic qualities, this metal becomes thereby still the more useful. Artificial magnets can be made of it, far exceeding the natural ones in strength. A very small magnet, turning freely on a point, is the needle of the mariner's compass, and pilots our ships through the trackless ocean.

While iron is cold, though it be tough and flexible, it is too hard and strong to be brought under the hammer, as some metals are; and, besides, it soon loses its toughness when we hammer it strongly, its latent heat being thus easily driven out of it. It retains its latent heat and toughness much better while it is drawn into wire; and it can therefore be drawn into very fine wire. Its cohesion is greatly

* An iron wire, of one-tenth of an inch in diameter, will carry 450 pounds. A copper wire not quite 300.

increased by this operation. When it is red hot, it is very malleable, and almost plastic like clay; and can be beaten by hammers, or compressed by rollers into very thin plates.

It is one of the most refractory metals, when in its purest state. The most intense fires can hardly melt it when it is exposed simply to the action of heat in close crucibles. In its unrefined state, it can be melted easily, and perfectly, by a violent heat, in the temperature $17,977^{\circ}$ Fahrenheit, or 130° Wedgewood: and the contact of the fuel increases its fusibility. Mr. Lewis says that gypsum has the same effect.

When pure or tough iron is heated to a white heat, 90° of Wedgewood, different pieces of it can be made to cohere and unite perfectly into one piece by hammering them into close contact. This is a common operation of the blacksmiths. They call it *welding*. Some sand, or pounded sand stone, is thrown into the fire in performing this operation. The sand melts on the surface of the heated iron, by uniting with a little of the metal that is calcined; and forms a liquid glazing, which defends the metal from farther calcination, and keeps the surface of the different pieces in a condition for uniting together, when they are properly applied to one another. Sand is of the same use here as borax is in soldering. This liquid glazing readily flies away from between the pieces, when they are hammered into contact.

The only defects of this metal are those of being too easily calcinable, and too liable to the action of different solvents. It is capable of being calcined so suddenly and violently, as to give all the appearances of inflammation: As,

1st, When heated to a white and dazzling heat, and suddenly exposed a to stream or blast of air, brilliant sparks are darted from it, which the metallurgists call *brandishing*. These are signs of the iron being inflamed, and calcining rapidly.

2dly, The fiery sparks produced by the collision of flint and steel are another example of it. They are small parts or rags of the steel, torn off by the flint. By the violence with which they are separated from the mass, and the extrication of latent heat, they are heated red hot; and in falling through the air, are blown up into an inflamed state. That it is not a simple ig-

nition or incandescence, occasioned by the great heat generated by friction, is evident from this, that if the same experiment be made in fixed air, they are then seen just like so many ignited particles of sand, and the light is seen only in the very spot where the collision is made : whereas the same sparks, in free air, are brightest when they have got to some distance, and seem to brighten by degrees as they recede from the stroke. Sometimes a brilliant spark is not seen at all, till at a considerable distance : and it branches and splits into two or three sparks. Also, when the two sets of particles are examined with a microscope, those that were driven off into fixed air are plainly thin rags of metal, which have been scraped off by the flint, and rolled up into a sort of spiral ; whereas those struck off into good air are scorified and blistered, and can be crushed to powder between the fingers. Nay, if a fine steel wire be twisted round a thick one, and if the whole be thrust red hot into a vessel containing vital air, the fine wire will take fire, and burn away like a squib, crackling and brandishing with great brilliancy.

3dly, Similar sparks are produced by throwing fine iron filings through the flame of a candle.

4thly, Larger masses of iron are easily made to burn in the same manner, by heating them in vital air, or introducing them red hot into it. It is this violent inflammation that makes the spark of iron struck off by flint kindle gunpowder with such absolute certainty. Were it merely red hot when struck off, it would be so much cooled in its passage, that it would produce no such effect. Other metals, equally or perhaps more inflammable, will not do, being too soft for producing the first heat by the stroke.

Iron, exposed to a mild heat gradually increased, is calcined at the surface, without producing any heat or light. The first phenomenon of this calcination of a bit of polished iron, is the appearance of rainbow colours on its surface, before the iron is red hot, but just approaching to that heat. The succession of colours is faint yellow, golden colour, purple, violet, and deep blue, weakened insensibly to a water colour, which is the last shade distinguishable before it is red hot. After this, a dusky crust and friable scales appear. When long calcined, the colour

is deep red. All the calces of iron, if much calcined, are either dusky yellow, red, or purplish. Hence they are called *croci*.

This succession of colours admits of a very satisfactory explanation, by the discoveries of Sir Isaac Newton concerning the colours produced by transparent thin plates. The colours succeed each other in that order in which they should follow, were they produced by a transparent plate, gradually increasing in thickness. Now we know that this succession of colours terminates in the production of a scale of calcined or oxydated iron. We also know that the calces of metals are frequently transparent coloured glasses; and, in all cases, compose such glasses by admixture with earths.

When iron is thus calcined, the power of the magnet over it diminishes; and when the calcination is carried to a certain length, becomes imperceptible. The scales are still attracted, but much more weakly than iron: and if further calcined, there is no more sensible attraction. Nor is the rust, formed by long exposition to the air, or any of the natural calces or ochres of a yellowish or reddish colour, attracted sensibly, in the common way of making the experiment. They are easily brought back again, however, to a less calcined, or less oxydated state, so as to recover the black or dusky colour of the scales: and then they are attracted by the magnet. We need only to mix them with a little charcoal dust, or any animal or vegetable matter, and make them red hot.

Iron is not only dissolved by several acids, but it is acted upon by all the saline substances without exception. They either corrode the metal, or dissolve the rust or calx. Water alone, or moist air, has considerable effect; and is perhaps the chief agent in all these corrosions. It has, therefore, long been a desideratum to preserve the surface of polished iron from corrosion by the air and weather, *i. e.* from rusting. The only method is to cut off the communication by some varnish. Oily or greasy matters are the fittest, especially such as harden in the air. Pure linseed oil, or hempseed oil, is therefore preferable, when spread over the iron, by rubbing it with a clean flannel cloth dipped in the oil, and rubbed on so as to leave no sensible

quantity. The very operation of polishing has a considerable effect; for it is always by the means of cutting powders, rubbed on with grease of some kind or other. The blue colour produced by heating the iron is also thought to defend it.

All the acids act on iron, and dissolve it. Even the carbonic acid, especially if assisted by water, dissolves it. For this reason, it is usual, in the manufactories of polished goods, to throw them into lime-water, or water having lime in it, to preserve them from rusting during the time that they are in the hands of the workmen. The sulphuric acid dissolves the iron the most readily and completely. But it must not be applied in its strongest state. It is necessary that a good deal of water be added at the same time. I had an opportunity not long ago to shew you how the iron is dissolved by sulphuric acid thus diluted, and the great quantity of inflammable air which is produced during the dissolution. The production of this inflammable air is undoubtedly best explained by the new theory of the French chemists. It proceeds from the water, which the iron decomposes.

The proofs of this are, 1st, When we force the strong sulphuric acid to act on iron filings, without adding water, but simply by heat, we do not get inflammable air,...we obtain sulphurous acid. And the acid, deprived of part of its oxygen, becomes sulphurous acid, which does not act readily on iron. This action requires a very great heat: and when the mixture is distilled to dryness, we obtain a sublimate of sulphur, deprived of all the oxygen with which it formed the acid. The solution of the iron, therefore, required more oxygen than was supplied by that part of the acid which really dissolved it, and combined with it. Even this ruddy compound of acid and iron is not completely neutralized, it being a very deliquescent salt; whereas the green-coloured salt, produced from a diluted acid, even falls to powder by evaporation.

2dly, Water alone can be made to act on iron, so as to produce inflammable air in great abundance. Even in the ordinary heat of the atmosphere, it produces some inflammable air, and changes the iron into a rust or calx. Iron filings, digested in pure water, are converted into calx; and a quantity of inflammable air is produced. To plunge red hot iron into water,

causes a thick black scale to form instantly on the iron, and much inflammable air is disengaged. This scale is similar to that which forms on iron simply heated in the air. This, I believe, suggested to Dr. Priestley a much more effectual way of applying the water, namely, in the form of steam, when the iron itself was red hot. It was sent through a porcelain or copper tube, in which iron wire is coiled up, and it converted the whole into the same calx; and inflammable air was disengaged. Water consists of oxygen and hydrogen, the basis of inflammable air. It appears, therefore, that the calx is produced by the decomposition of the water, which oxydates the iron, while the inflammable air escapes.

When the diluted acid acts on iron, as the solution goes on, a double operation seems to be going forward. There is a copious formation of a black mud, which is of the same nature (at least a great part of it) with the oxyd formed by iron and water. This seems to be a different process from the saturation of the acid: for, if the acid has been but little diluted, the solution stops, but is renewed by adding more water. The water of the acid is employed in forming the martial salt; and now the acid has not enough to continue this formation, till fresh water be added. But the mud is an oxyd deriving its oxygen from the water only.

When the sulphuric acid is saturated with iron, and the effervescence ceases, the solution is muddy for some time, but at last becomes clear, and of a light green colour. The matter which made it muddy is observed partly at the bottom, and partly at the top. It is of a blackish colour, and resembles the dust of what is called *black lead*, or *plumbago*. Professor Bergmann analysed this blackish sediment, and found that it has really the qualities of plumbago, which had been analysed before by Dr. Scheele. It is composed of carbon, united to a small quantity of iron. If we take either black lead of the finest kind, or the black matter now spoken of, and expose it to the most intense heat in close vessels, it suffers little or no change. But in open air, it is all consumed, except an ochry calx, variable in quantity. But much of it escapes, by being volatilized without change. It detonates with nitre, requiring

a very great proportion of nitre to finish the detonation entirely. We obtain carbonic acid by this process: and the nitre, besides being alkalized, contains some ochre, and is greatly diminished in quantity. It would seem that these things happen, because this combination of carbon requires a heat for its combustion so much greater than charcoal does, that the nitre must be raised to so high a temperature that much of it is dissipated in vapour. Plumbago may therefore be considered as a species of charcoal, which has a small quantity of iron for its basis, instead of the small portion of earth and salt contained in common charcoal.

To free the solution of iron from this black matter, it must be filtrated, and then evaporated. It gives green crystals, called *green vitriol*, or *sal martis*. Great quantities of it are used in some of the arts by the name of *copperas*; but it is made by a much cheaper process. These crystals contain much water. They undergo the watery fusion and spontaneous calcination. The matter which remains, after the water is evaporated from them, is called *calcined vitriol*: and, according to the degree of heat employed, vitriol is calcined to whiteness,...to light red,to redness,...and lastly, we have *colcothar* of vitriol. The heat applied enables the iron to act powerfully on the acid, and to attract from it a part of its oxygen. Hence the metal becomes highly oxydated: and in that highly oxydated state it has a deep red colour. From this compound the vitriolic acid was formerly obtained; whence its name. And it is still used in some processes, in which the action of the vitriolic acid is necessary, as in the old process for aquafortis.

I presume that you now see the propriety of considering vitriol, and other metallic salts, formed by an union with acids, as salts of a secondary order of composition; one of their ingredients, namely, the acid, being avowedly a compound of oxygen and another base. Hence arises the difference of the salts formed of the same metal and different acids. We must therefore consider vitriol and colcothar as very different from the black *æthiops martialis*, from which the carbonic acid has been expelled. This is a compound of iron, and oxygen: but colcothar is a compound of iron, and oxygen, and sulphur*.

* There is here some difference of opinion among the chemists, or at least in the way of conceiving this circumstance. By proper treatment, all the acid

The nitric acid, the next in order, is seldom applied to the metals in its strongest state. In that state, it contains too little water to dissolve the compounds which it forms with the metals. In dissolving metals with it, we commonly employ it diluted with an equal quantity of water: and in this diluted state it is called *aqua fortis*.

If we attempt to dissolve iron filings in *aqua fortis*, in the same manner as when we dissolve them in diluted sulphuric or muriatic acid, the action of the materials is rapid; the mixture becomes hot in a moment; and there is an outrageous effervescence, or a sort of explosion. The acid is changed into elastic red vapours and incondensable gases. The iron attracts the oxygen of the acid with too much violence, and in too great quantity. It decomposes too much of the acid; and is itself oxydated to so high a degree, that it requires a very large quantity of the acid for its dissolution. The acid employed is, therefore, not sufficient for dissolving it, and the iron is only corroded.

To dissolve iron well in this acid, we must moderate the action of the metal and acid on one another, by preserving them cool, and adding the iron very gradually, and with much less surface for the acid to act on. In this way, an ounce of *aqua fortis* dissolves only 26 grains, somewhat less than one-eighteenth.

There never is any inflammable air produced during this dissolution of the iron in the acid of nitre, nor in dissolving any other metal in that acid. The reason is plain. The iron, while

may be expelled from the green vitriol by heat: and the iron is left combined with about one-half its weight of pure oxygen. The name of *colcothar* is given also to this oxyd by several eminent chemists; while others consider *colcothar* as this very oxyd, with this dose of oxygen, but farther combined with a small portion of sulphuric acid. They consider green vitriol as another oxyd, having a much smaller dose of oxygen (about $\frac{27}{100}$) combined with a much larger dose of sulphuric acid. They think that iron has only these two states of oxydation, and that the apparently different states in which we see it, are only mixtures of these oxyds. This doctrine or view of the matter is to be found very distinctly expressed in a dissertation of Mr. Proust on Prussian blue. This variety of opinions is very embarrassing, when we read the explanations given of other phenomena: and a theorist may often shift his ground in describing the internal procedure.....EDITOR.

dissolving, is disposed to attract a quantity of oxygen: but it easily obtains it from the acid. The nitric acid abounds with this principle; and contains it in a more loose, and separable, and active state, than the sulphuric or muriatic acids do in their ordinary form. The iron, therefore, gets it readily from the acid: and no part of the water seems to be decomposed, nor is any inflammable air produced.

When the iron is dissolved in this manner it first tinges the aquafortis of a fine green colour, and some thin red vapours of the nitrous acid make their appearance. And by afterwards gradually adding a little more iron, the acid becomes saturated, and will not dissolve any more. Then the red vapours gradually disappear by flying away; and the colour of the solution changes to a pale brownish yellow.

The green colour, which appears at first, is therefore produced by the presence of the nitrose acid in the solution; since the colour disappears as soon as this acid has time to evaporate entirely. You no, doubt, remember, that the nitrous acid always gives a green or blue tincture to water with which it is diluted; and that when this volatile acid is allowed to evaporate, the colour disappears.

You will now better understand the reason of the violent outrageous effervescence which happens, when, in place of taking this method, we throw a quantity of fine iron filings into the aquafortis. The acid is allowed, in this case, to act on a very extensive surface of the iron, and to come into contact with a great quantity of it at the same time. It therefore dissolves a small part of the metal, and corrodes the rest with the greatest rapidity, or in a moment of time. But this rapid dissolution and corrosion is attended with two accidents: *1mo*, The sudden change of the nitric acid into the nitrous acid, by abstraction of its oxygen; and *2do*, With the extrication of a great quantity of latent heat from the iron. The mixture becomes so hot in a moment, that the glass is too hot to be touched. This heat gives great elasticity, and a deep red colour, to the nitrous acid vapour; and thus is produced that sort of explosion.

We cannot obtain crystals from this solution by evaporating it with that intention: but I have got remarkable crystals from it by accident, of an amethystine colour.

Chemists have often observed a smell of volatile alkali in the decomposing metallic salts by fixed alkalis and by lime. It passed unheeded, being attributed to impurities in the alkali or lime, which are known to be generally contaminated by a minute portion of volatile alkali.

But, in the decomposition of a fresh-made nitrat of iron, this smell is very remarkable, if the arbitrary circumstances of the experiment chance to be favourable. Thus, take two drachms of aquafortis, and dilute it with four of water, so that the action on the metal may be very moderate. Dissolve two drachms of clean iron filings in this diluted acid, keeping all as cold as possible : and when the solution seems ended, add three drachms of slaked lime. There will be little effervescence during solution ; and the lime will immediately occasion a very strong smell of volatile alkali. The formation of this gas is so copious that we can even make its escape visible. Moisten the inside of a tall glass (like a beer glass, or small cylinder) with oxygenated muriatic acid, and hold this over the mouth of the solution glass : and it will instantly be filled with a white cloud, and the sal ammoniac will fall down like snow.

This is one of the most interesting experiments in chemistry,...and eminently instructive. There was not an atom of volatile alkali in the materials. It must, therefore, be produced by a separation, and a new combination of simpler substances contained in them. We can now guess at the hidden process, by what we know of those materials. The filings of iron decompose water, by attracting its oxygen, and set the hydrogen at liberty. We know also, that, by the same strong attraction for oxygen, it decomposes the nitric acid, and sets its azote at liberty ; or, at least, in a state of redundancy, as an ingredient of nitrous gas. We do not know of any other substances being disengaged from their former combinations in this experiment. It would not, therefore, be unreasonable, though perhaps a little hasty, to conclude that these two substances have united, and by their union, compose volatile alkali. Dr. Priestley, by passing the electric spark through volatile alkali a great many times, either extricated or produced a vast quantity of hydrogenous gas. It is very true that Dr. Austin (*Phil. Trans.* 1788)

could not combine those gases by heat, nor by the electric spark, so as to produce ammonia. But he could not expect it, since the electric spark separated them. Scheele found that when metallic oxyds are reduced by ammoniacal gas, a great quantity of azotic gas is *extricated*. His former experiments did not permit him to say that it was *produced*; because they had convinced him that it is a primitive substance. Bergmann, therefore, was disposed to think that volatile alkali consisted of the two substances, azote and hydrogen.

Dr. Austin could not combine the gases by heat. This is not an objection. Heat combines oxygen and azote in the same manner as it promotes all combustions. But here is no combustion. There are many other examples where the bases of the elastic gases combine, although the gases themselves will not, being hindered by their combination with caloric. I take this to be one. The two substances meet in the very instant of their extrication from their former combination. Dr. Austin succeeded, however, when only one of the substances was in the gaseous state. Iron filings, moistened with water, were put into a small quantity of azotic gas, confined by mercury. The volatile alkali was produced.

The operation of the quicklime in the experiment which led me into this discussion is very evident. It prevents the instant union of the volatile alkali with some of the acid; or it decomposes the nitrous ammonia as fast as it is formed. The want of this prevents the appearance of the volatile alkali in every solution of iron in nitric acid.

On the whole, I consider this as a very distinct fact in confirmation of Bergmann's sagacious conjecture, and a corroboration of the proofs which Mr. Berthollet has given of the same opinion. I have already mentioned several of them, in my account of hydrogen, drawn from a variety of sources. I believe I forgot to mention a very distinct one, which, I think, admits of no other explanation. When the vapour of oxygenated muriatic acid is passed through the pure vapour of volatile alkali, both disappear, and we get a watery solution of common muriatic acid, and a quantity of azotic gas; and heat is produced. The redundant oxygen of the muriatic acid attracts the hydrogen of volatile alkali,

and forms water, setting the azote of the alkali at liberty. There was nothing else in the materials that could yield azote, nor any other way in which it could be detached.

The muriatic acid dissolves iron with effervescence, occasioned by the production of inflammable air, which is the same in quantity and quality, or very nearly the same, with that produced by the sulphuric acid and iron. When the iron is dissolved, and the acid is saturated, we have a solution which has a green colour, like the solution in sulphuric acid, and in which there is also some *plumbago*, which makes it muddy, and must be separated by filtration. To have these phenomena in the best manner, use the following proportions: Iron, one ounce; muriatic acid, six ounces (equal in bulk to $5\frac{1}{4}$ of water); and add $2\frac{1}{2}$ ounces of water. Thus we have it of a clear green. It readily affords crystals of the same colour.

These crystals are not affected by heat in the same manner as the vitriol or sulphat of iron. We can gradually expel the sulphuric acid from iron, by the force of heat: and the iron remains in the state of an oxyd. But when we attempt to expel the muriatic acid in the same manner, a great part of the iron is volatilized by it. Thus, if we expose a compound of iron and muriatic acid to heat in a retort, and gradually increase the heat to the greatest degree which the retort can bear, no part of the acid arises pure: but what rises first, however, is less charged with iron, and condenses into a yellow liquor. What follows this is combined with more iron, and condenses into shining deep yellow or black scaly crystals, in the neck of the retort. In the bottom of the retort remains a mass, concreted into scaly crystals.* It consists of a greater part of the iron, retaining a portion of the acid, but not enough to give it volatility. All this agrees with other phenomena, in shewing that metals have a stronger attraction for the muriatic acid than for either of the other two fossil acids.

* This sublimate is deliquescent. When mixed with thrice its weight of sulphuric æther, and digested, the æther takes all the colour to itself. Seven parts of alcohol added to this, forms Bestuscheff's drops, a medicine of high character on the Continent. It becomes colourless by a few minutes exposure to the sun's light....EDITOR

The muriatic acid dissolves iron readily also, when this acid is combined with water in its oxygenated state: but then there is no effervescence of inflammable air. The only effects produced are, that the iron is calcined and dissolved, and the acid returns to the state of common muriatic acid. The solution is, therefore, not different from one produced by dissolving iron in common muriatic acid, excepting that no inflammable air is produced. The reason is evident. The oxygenated muriatic acid contains plenty of oxygen to satisfy the attraction of the iron for this principle. No part of the water therefore is decomposed, nor any inflammable air produced from it. In this respect, the oxygenated muriatic acid is similar to the nitric acid,...in the action of which upon metals inflammable air is never produced.

Thus, I have described the action of the three fossil acids on iron, when applied to this metal in its ordinary metallic state. If the iron be previously calcined before these acids are applied to it, it can be dissolved by them in this state also, but with more difficulty, and in less quantity; much more acid being required to dissolve an ounce of calx than an ounce of iron. And such dissolutions are performed without effervescence, except when the calx happens to be combined with carbonic acid.

The muriatic acid dissolves the calcined iron better than other acids. But even of this acid a much greater quantity is required to dissolve calcined iron than metallic iron, and always a greater quantity in proportion as the iron is more calcined. The colour of the solution also is different from that of the solution of metallic iron. Instead of being green, it is yellow. There is no inflammable air produced on this occasion; nor is it to be expected: for the iron being used in the state of a calx, or already combined with oxygen, has no power to attract oxygen from the water, or to decompose any part of it.

This yellow colour, which is very like that of the solution of gold, has often misled visionary and ignorant chemists, and made them imagine they had discovered gold in earths and stones, and other minerals, of which there are a great number containing iron in the state of a calx, and therefore disposed to dissolve in muriatic acid, and to tinge it of the same yellow colour.

The vegetable acids act also on iron, and by uniting with it, give it a soluble saline form. But they dissolve it much more slowly than the fossil acids, and require to be assisted by digestion. They produce solutions of a green colour at first, but changing, by time and the action of the air, to a russet, or rusty colour. This, or some similar change of colour, happens to all the solutions of iron, when they are kept for some time, and especially if they are exposed to the air. And if they were saturated with the iron at first, they are sure to deposit a part of it, in the form of ochre, or of a rusty coloured calx. Fourcroy says that the calx of iron, dissolved in the acetous acid, gives us a solution of a fine red colour. The separation of part of the iron in this manner is much promoted by boiling such solutions in an open vessel, or by evaporating and diluting them repeatedly. By adding more acid, we can in most cases redissolve the iron or calx, which is separated, and make the solution clear again.

I have been long accustomed to explain this separation of part of the iron from its solutions and change of colour which these undergo, by shewing that it proceeds from a farther oxydation which happens to this metal after it is dissolved. During the effervescence which appears while the iron is dissolving in the sulphuric or muriatic or acetous acids, this metal is oxydated to a very moderate degree only; but after it is dissolved, it undergoes a farther oxydation. The dissolved iron continues to act still, though much more slowly than at first, upon the water, and to attract oxygen from a small part of it, or perhaps from the air contained in the water. And the iron, by becoming more oxydated, has its attraction for acids diminished. It requires a greater quantity of the acid to keep it dissolved. Hence the quantity of acid which was sufficient at first, is insufficient afterwards: and some of the most oxydated part of the iron separates in form of ochre or calx.

That this is a just account of the phenomena, is proved by several facts. *1st*, Recent solutions of metallic iron emit an odour of inflammable air, and continue to emit it, though not so strongly, for a long time after they are made. *2dly*, Changes of colour, which happen in them by keeping, are

always such as to end in the colour produced by dissolving a calx in the same acid. *3dly*, An old solution, which has suffered this change of colour, will resume its primitive colour, if some fresh iron be dissolved in it by means of a little additional acid. The fresh iron, while dissolving, reduces the other to a less calcined state, by taking from it a part of its oxygen. *4thly*, The calces of iron, otherwise produced, are well known to be less dissoluble than iron. They require a greater quantity of acid to dissolve them, in proportion as they are more calcined. And they have much less attraction for acids than iron has which is less calcined.

From this change which happens to the solutions of iron, you will easily understand the origin of the great quantity of ochre; or yellow calx of iron, which mineral springs, containing vitriol of iron, deposit in their course. In the same manner is produced the durable yellow stain which all the solutions of iron leave upon white cloths, on account of which some are used in painting linens. The metal is introduced in a dissolved state into the very substance of the fibres: and there, by the action of air, which calcines it to a great degree, it is deposited in the form of ochre, which never can come out until it is again dissolved. This also points out the proper method of removing those stains, viz. by applying such acids as can safely be used to redissolve the iron. The muriatic acid is the most powerful dissolver of the calces of iron: and when applied weak, effectually takes out the stain, without injuring the cloth in the least. Some vegetable acids also, such as the acid of tartar, are very effectual. And even the sulphuric acid may be used for this purpose, if applied with caution, and in a proper state of dilution. The nitric acid has little action upon the calces of iron. It is rather disposed to render them more difficult of solution; and is actually employed for this purpose in some processes.

You will also understand the propriety of the process given in the last edition of the *Edinburgh Pharmacopœia* for *Tinctura Martis*.*

Alkalis, in their ordinary state, shew little power to act upon iron. We commonly evaporate watery solutions of

* Vide Dispensatory.

the alkalis in iron vessels, when we wish to have the alkalis in a dry state: and they neither corrode the iron, nor are sensibly tainted by it. If we add alkalis to solutions of iron in acids, they precipitate the iron. If the sulphat of iron be recently made, the precipitate is bluish green. It is in that state of very moderate oxydation to which the iron was reduced during its dissolution. But if it stand a while exposed to the air, or when the water in which the precipitation is performed contains plenty of good or respirable air, the precipitated metal attracts more oxygen, and changes its colour, and becomes ochry or rusty coloured. Scheele found that the rapid exhibition of this colour was the surest test of the presence of vital air in water. (*On Fire, &c.* No. 94.) It is evident that the yellow colour which the oxyd assumes, is in consequence of its becoming more oxydated, or absorbing more vital air. It is also very much disposed to absorb carbonic acid, when in this state.

In some cases of the precipitation of iron by an alkali, the precipitate can be re-dissolved by adding more alkali. The most noted example of this is in the precipitation and redissolution of the nitrat of iron. The blood red solution thus obtained is called the *tinctura martis alkalina* of Dr. Stahl.

But among the most remarkable effects produced by alkalis on the solutions of iron, are those of the PRUSSIAN ALKALI, or LIXIVIVUM SANGUINIS.

Lixivium Sanguinis.

This is a preparation of alkali discovered by a Prussian chemist named Diesbach. He evaporated blood to dryness, and mixed it with half its weight of fixed alkali: and roasted or charred the mixture with a strong heat, till little or no more fumes arose from it. He dissolved this charry matter in water; and filtrated the solution, which had a deep brown colour, and a strong disagreeable smell. When the lixivium is thus cleared of impurities, and brought to a proper degree of concentration by boiling, it is then called LIXIVIVUM SANGUINIS; PREPARED ALKALI, and PRUSSIAN ALKALI.

If this lixivium be dropped into a fresh made solution of iron in sulphuric acid, to which a few drops of muriatic acid have been previously added, we shall see each drop of the lixivium produce a fæcula of the most rich and beautiful blue, which will slowly descend to the bottom, and there collect. It may be separated by decantation, and repeated washings with water. Without the muriatic acid, it is generally tainted with a brown or yellow ochry matter. This fæcula is manufactured for a pigment, by the name of PRUSSIAN BLUE.

The most minute quantity of iron in a mixture becomes discernible by this addition, which is therefore a trial of the presence of iron in mineral waters.

The colour of this precipitate is not liable to fade in the air; neither is it altered by diluted acids. It manifestly depends on a matter which is joined to the iron, and precipitates with it; the iron having received it from the alkali by a double elective attraction; the alkali combining at the same time with the acid which had dissolved the iron. These are the manifest facts.

This is further proved by an experiment described by Mr. Lewis, in his *Materia Medica*, and also by Macquer. In this experiment, this blue précipitate is decomposed by digesting it with a dissolved alkali. The iron is suddenly deprived of its colour: and the alkali shews that it has attracted a part of the tinging matter, for it will now precipitate iron blue. This shews that a particular matter is combined with the iron in the blue precipitate, which matter can be taken from it and restored again.

A careful examination of the phenomena in this experiment shews that, on the one hand, the alkali poured on the Prussian blue not only abstracts the colouring matter, but also dissolves some of the oxyd of iron; for an acid added to it will make it deposit some Prussian blue. This seems to happen, because the added acid first dissolves this oxyd, and the solution is immediately acted on by the Prussian alkali, and thereby precipitated blue.

On the other hand, there is the same evidence that the ochry matter left by the alkali is not an ordinary calx; for when an acid is poured on it, we have a blue precipitate.

Mr. Berthollet says, that after repeatedly washing the calx left by the alkali, with water, which comes off clear, we still at last obtain a blue precipitate. How this is produced will be explained afterwards : but in the mean time, we see that some of the tinging matter remains combined with the iron.

Therefore the alternate treatment with acids and alkalis, and the concomitant production and removal of the blue precipitate, must have a period. We shall see presently that the colouring matter is ultimately decomposed by this treatment.

But we have also learned by experiments, that there is not enough of this matter in the *lixivium sanguinis*, as it is usually prepared, to convert the whole of the precipitated iron into blue precipitate ; and that a good deal is in the state of an ordinary oxyd. Hence we perceive the use of the muriatic acid in preparing the blue precipitate. It is necessary for re-dissolving that part of the iron which is precipitated in the form of ordinary calx, and which spoils the colour. There is no danger that the acid will dissolve any part of the blue precipitate. It resists the action of acids in their diluted state.

The nature of this matter, which is joined to the iron in the blue precipitate, is singular and surprising. It appears to be a sort of ammoniacal compound. It contains a volatile alkali, intimately combined with a very peculiar volatile matter, which is inflammable ; the vapour of it readily taking fire ; while at the same time, it partakes also of an acid nature, or has an attraction for alkalis, alkaline earths, and metals.

But when this acid sort of matter is combined with alkalis alone, it adheres to them with a force which is very weak. It diminishes very little their alkaline qualities ; and is easily separated from them by the weakest acids, even by fixed air. There is only one way by which it can be made to adhere strongly to the alkaline salts ; that is, by adding to the compound some of the metallic substances, particularly iron very slightly oxydated. A small quantity of the iron is dissolved by the compound of alkali and tinging matter ; and thus is formed a compound of three ingredients, all of which cohere together much more strongly than the volatile tinging matter

and the alkali did before by themselves. Mr. Macquer first gave us somewhat of a distinct notion of it, by demonstrating the double exchange which happens in the formation of the blue precipitate. Dr. Scheele discovered the particular substance in which the colouring power resides, and investigated several of its chemical relations. His experiments are to be seen in his chemical essays, translated by Dr. Beddoes, 1786. Mr. Berthollet prosecuted the discovery of Scheele, and has greatly added to our knowledge of this remarkable substance.

The triple compound I just now mentioned is formed at once, either by adding a calx of iron to the *lixivium sanguinis*, or by mixing a solution of pure fixed alkali with the blue precipitate, as in that experiment I lately mentioned; and thus the alkali can be completely saturated and neutralized. The solution of it in water has a yellow colour, from the iron which it contains. It can be separated from water by evaporation, and in some measure crystallized into flakes or scaly crystals; or it may be made to separate from the water, and to crystallize suddenly by means of alcohol. If into a saturated solution of Prussian alkali, somewhat inspissated and filtrated, we pour an equal measure of alcohol, the mixture becomes immediately thick by shaking, and the precipitated matter appears a soft granulated substance, like soaked rice. By long keeping, some spirit separates to the top, and the granulated matter becomes scaly.

I said just now that the common process for preparing the Prussian alkali is to mix the alkali with dried ox-blood, and burn the mixture to a charcoal, from which the alkali is extracted with water. But several other ways to prepare this alkali have been discovered.

All the animal substances, from which a volatile alkali can be formed or extricated by heat, will serve as well as dried blood to be mixed and charred with the alkali. Horn shavings, hair, wool, pounded bones, &c. are extremely fit for this purpose. And Dr. Scheele prepared a very good Prussian alkali, by making fixed alkali and charcoal dust red hot, and then thrusting down a little mass of sal ammoniac to the bottom of the crucible, and continuing the mixture for a short

while in a low red heat. This shews that a volatile alkali is necessary to the production of this tinging matter.*

This effect of the *lixivium sanguinis* on solutions of iron, is the foundation of the art of preparing the colour called Prussian blue, for painters, and other artists. The chemist who first discovered it, lived at Berlin, and kept it secret for some time, that he might sell the blue at an high price: and hence it is called Berlin, or Prussian blue. Many chemists have made experiments on it, and endeavoured to investigate the nature of it, and to improve the art of preparing it, of which you may see many examples in the *Memoirs of the Academy of Sciences*. But the greatest progress has been made by Mr. Macquer, by Scheele, and by Mr. Berthollet. (See *Dictionary of Chemistry*, *Scheele's Essays*, and the *Annales de Chymie*, also *Note 52. at the end of the Volume.*)

I must not, however, omit informing you that the Prussian blue of the shops has other ingredients besides the vitriol and Prussian alkali. This would produce a pigment almost black, so intense is its colour. A great quantity of alum is used in the preparation. Its acid adheres very loosely, and saturates the alkali which is not already combined with the Prussic acid. Of this there is always a great portion, even after the most careful preparation. The alum being thus decomposed, its earth, which is a snowy white, dilutes the intense blue, without discolouring it. It is better liked in this state. But surely the painters will find it much less powerful in mixture with other colours.

Mr. Macquer contrived a very ingenious method of depositing this most beautiful colour on cloth, paper, &c. The stuffs are first soaked in a solution of vitriol and alum. When thoroughly impregnated, they are dipped in the *lixivium* of Prussian alkali. Any ochry matter in the precipitate may be removed by dipping into a vitriolic or muriatic acid, greatly diinted.

* A mixture of chalk with the sal ammoniac greatly improves the process, and is the most certain and expeditious method for obtaining Prussian alkali....

Such are the different ways of precipitating iron from acids by alkaline salts. We may next subjoin to these precipitations an account of the effect of astringent vegetables upon the solutions of iron.

By astringent vegetables are meant those whose juices have the power to contract animal fibres, and which, when tasted, occasion a sensation in the mouth as if they produced that effect there. They seem to draw the mouth together. More or less of this quality is found in a great number of vegetables. It is remarkable in sloes, and many other unripe fruits, and in all parts of the oak,...the leaves, the bark, the juices, and the galls, which are a tumour produced by extravasation of juices. Galls are the most powerful astringents.

If a decoction of any of those vegetables be thrown into any solution of iron in an acid, the mixture immediately becomes a dark blue, or black; and its transparency is greatly diminished. This may be called a precipitation; although a great portion of the black *fæcula* will remain suspended for any length of time in close vessels; for the greatest part of it may be separated by filtration.

I introduced the mention of this effect of astringents among the precipitations of iron, because, although it is not commonly a precipitation, but generally a mere change of colour, especially at first, there are however some astringents, logwood, for example, that actually separate the iron from the black sediment, especially when much diluted. Besides, a little acid destroys the colour, and a little alkali restores it: indicating, I think, that the astringent matter was imperfectly separated from the acid,...seeing that more acid destroys the colour, by bringing the iron into more perfect solution. The added alkali restores things to their former state, merely by saturating the acid.

These experiments shew some sort of power in astringents to loosen the cohesion of iron with acids. There are other experiments which shew that they have a disposition to unite with the iron themselves, and to dissolve a small quantity of it. Several chemists, therefore, have chosen to consider the matter which thus affects the iron as an acid: and they have named it

the GALLIC ACID, because most abundant in nut galls ; and they think that the iron has a stronger affinity with this than with the sulphuric acid, and precipitates with it from vitriol.

A surprisingly small quantity of dissolved iron, and astringent vegetable matter, have a perceptible effect on one another in this manner. If a little infusion of green tea, for example, be spilled on a knife, it soon becomes tinged with an inky blackness. The astringent matter of the tea acts on the knife, and dissolves a minute portion of the iron, with which it produces that appearance : or if a knife, or any thing made of iron, be laid on a wet table, the table, especially if oaken, is stained black where it is touched by the iron. Hence this experiment too, as well as that with the Prussian alkali, is used as a test of the presence of iron in mineral waters.

The black colour also given to silk, wool, leather, &c. by the dyer, depends on this effect of astringents and iron. The principal materials employed in those arts are always some of the compounds of iron with acids, (generally vitriol or sulphat of iron) and some of the astringent vegetable substances. Common tanned leather requires only vitriol, because it is already impregnated with the juice of oak bark, one of the most powerful astringents.

We also derive from these discoveries the art of making the ink now used for writing, which is an object well worthy the attention of the chemist ; as upon the perfection and durability of it may often depend the preservation of important records, or valuable manuscripts. The art of making good ink has accordingly been studied by several chemists. (*See Caperarius de Atramentis*) and by none so thoroughly as by Mr. Lewis, who published his experiments in his *Philosophical Commerce of Arts*, to which I refer you upon this article. He found that galls, when found, are the best of all the astringent vegetable substances, especially for durability. Logwood concentrated the colour, by combining more iron in the composition, by nearly one-fifth. One part of recently made vitriol to three of galls seemed the best proportion. More vitriol made the writing blacker at first, but greatly impaired its power to resist the action of air and light. Gum-arabic both hinders the ink from

spreading, and proves a varnish, which defends the composition from the air. The ancients wrote with levigated charcoal, the most indestructible substance we know. And accordingly, the writings found in *Herculaneum* are still a perfect black. They were pigments. Their defect is, that being superficial, they may easily be erased, whereas the ink of modern times penetrates into the paper. Dr. Lewis combined the two inks very satisfactorily, by mixing some fine lamp black with his ink, in such quantity only as to make it very sensibly blacker at first. This ink withstood all action of the weather. It ran from the pen with abundant ease. I recommend this paper of Dr. Lewis as being also a good example of the chemical investigation of any complicated subject, and for many judicious and useful incidental observations through the whole. I shall only add to what he recommends, the use of a small quantity of cloves, and to keep the ink in a cool and dark place, and not too long. The reason of this last caution is the corruption of the vegetable astringent. The effect of the cloves is to retard this, and to prevent the formation of mould upon the surface.*

* As vinegar has not the power to dissolve and discolour this black compound, Dr. Lewis recommends vinegar or wine as the best solvent of the materials. It undoubtedly becomes more durable: but it is found to soften the nib of the pen so much that it is quickly worn away by the paper. The great art in ink-making is to have a superabundance of astringent matter, to counteract the disposition of the iron to a farther calcination, which renders the ink brown. It would be a great improvement in the manufacture of writing paper, if some astringent matter could be introduced. A little ardent spirits effectually prevents the spoiling of ink by keeping, but makes it sink and spread. Corrosive sublimate prevents mouldiness *completely*.

A GOOD PROPORTION FOR WRITING INK.

Rasped logwood	1 ounce.
Best gall nuts in coarse powder	3 ounces.
Gum-arabic in powder	2 ounces.
Green vitriol	1 ounce.
Rain water	2 quarts.
Cloves in coarse powder	1 drachm.

Boil the water with the logwood and gum to one half; strain the hot decoction into a glazed vessel; add the galls and cloves; mix and cover it up. When nearly cold, add the green vitriol, and stir it repeatedly. After some days, decant or strain the ink into a bottle, to be kept close corked, in a dark place.

A ruddy fryable gum resin, not unlike gum-kino, from New Zealand, was given me by a friend. Finding its taste remarkably astringent, and the whole

Of the compound salts, I observed formerly that none are so remarkable for their effects on the metals as nitre and sal ammoniac.

Nitre deflagrates violently with iron in a strong heat, and is alkalized, or its acid is decomposed and dissipated, as in the other cases of deflagration with this salt. The alkali remains mixed with the calx of the metal, and is caustic; in consequence of which it acts on the calx, and unites with a part of it, ...rendering it soluble in water to a certain degree along with itself. But this solution is not permanent.

Sal ammoniac and this metal act remarkably on one another. I pointed out the reason of this in treating of metals in general, namely, the volatilizing power of the muriatic acid. Common sal ammoniac contains the acid which has the strongest attraction for the metals; and this acid is combined with the weakest of the alkaline salts,...the alkali which has the weakest attraction for acids in general. Accordingly, if we mix together equal weights of sal ammoniac and iron filings, and grind these materials well in a mortar, they soon after begin to act;...the matters grow warm,...the more readily, if a little humidity be added. The sal ammoniac begins to be decomposed; the acid joins itself to the iron; and the volatile alkali is detached, and shews itself in a separated state by its pungent odour. There is also separated at the same time a quantity of inflammable air, the odour of which mixes itself with that of the volatile alkali. This inflammable air is produced by the decomposition of some of the water. The action of these materials, and the decomposition of the sal ammoniac, are not complete, however, until we apply heat to the mixture in glass vessels. Then the sal ammoniac is totally decomposed, and a caustic volatile alkali rises, which it is almost impossible to condense completely, on account of its being accompanied with inflammable air. The whole of the acid remains combined with the iron in the retort.

very mucilaginous, I mixed some of it with ink-powders, and found that it improved the ink in a very remarkable manner, both deepening the colour, and giving it body. Writings with it, and with ink made by Dr. Lewis's receipt, on a card, being exposed to the weather on a south wall, this addition was found to have increased its durability surprisingly.....EDITOR.

All these effects are also produced on sal ammoniac by the calces of iron, with this difference only, that it requires a larger quantity of the calx to decompose the whole of the sal ammoniac, and that, during the action of the materials, there is no heat or inflammable air produced.

But when sal ammoniac and iron are made to act on one another, it is not usual to take such a large proportion of iron, or of calx of iron, as will decompose the whole of the sal ammoniac. There is a preparation obtained from sal ammoniac and iron, ordered in both the London and Edinburgh Pharmacopœias, under the title of FLORES MARTIALES. This is produced by mixing with the sal ammoniac such a quantity of iron filings, or of a calx of iron, as is sufficient for decomposing only the half of the sal ammoniac: and this mixture is exposed to heat in proper vessels. First, we obtain a caustic volatile alkali, detached from that part of the sal ammoniac which is decomposed. After this has come over, the heat is increased, to make the entire part of the sal ammoniac arise, which requires a much stronger heat. The vapours of it condense into a solid matter, or what is called FLOWERS. But while it arises in this manner, it carries with it a part of the compound of acid and iron that was formed in the beginning of the operation. This compound is in some degree volatile, when there is enough of acid combined with the iron. A part of it, therefore, rises, and is condensed with the sal ammoniac; and forms the reddish and yellow flowers to which we give the name of *florcs martiales*.

It is found that an oxyd, instead of the metal in its purest state, ensures the desirable appearance of this preparation,... the red and yellow colour of the flowers. Therefore, when filings of iron are employed, it is of considerable use to expose them for some time to the damp air of a cellar. An oxyd still more replete with vital air, such as colcothar is, more certainly produces red flowers. (*See note 53. at the end of the volume.*)

Iron in its calcined state can be mixed in fusion with vitrified earths; and the glass compound is tinged of various colours, according to the quantity of the iron, and the degree to which it is calcined. The colour which this metal most readily communicates, is a green, like that of its solutions in acids. Such

a green is seen in the common glass of which bottles are made, and in crown or window glass : and the green phials of the apothecaries are tinged with iron. But when the calx of iron is very highly calcined, it will sometimes give a dull yellow colour, and a red. And in all cases, when much of the iron is added to the glass, the colour is increased or darkened, so much as sometimes to produce almost a blackness.

It is owing to the presence of this calx, in some degree or other, in almost every fossil body, that our clays are in general so much disposed to vitrify, when urged by great heats. A very minute portion of it gives an incipient vitrification to the best of them ; and produces the compactness that is so desirable in all, with very moderate heats. It is this which gives the red colour to our common brick and tile.

Such bricks are unfit for the construction of furnaces ; because a moderate heat makes them run into slag. The greenish yellow colour of the small Dutch bricks is not owing to a want of iron, for they contain a great deal, but to the presence of magnesia. The grey stock bricks of London have supplanted the red bricks, which are now to be seen only in the old houses, but are inferior to them in their power to resist the weather.

Experiments made with the different earths have shewn that the flinty is the most disposed of any to unite with calx of iron in the fire, and be melted by it. Hence the use of it in welding iron.

The effects of sulphur and iron on one another deserve particular notice.

Sulphur unites very easily with this metal in the dry way, or by fusion, as with most others. And it penetrates iron more quickly than most other metals, shewing thereby a stronger attraction for it. A bar of iron, thrust red hot into melting sulphur will presently melt and drop off like wax held in hot water, with a bright dazzling glow.

Also, if one part of flowers of sulphur be ground with five parts (by weight) of fine iron filings, and the mixture be put into a thin glass vessel, such as a matrass, or cucurbit, and if this be held over clear burning coals, we shall observe the sulphur begin to shew softness very soon, sticking to the side of the glass, long before the heat has arrived at that degree that would

otherwise produce this effect on sulphur unmixed. It does not rise much in its temperature for a good while. Then, it suddenly becomes fluid all over, and the filings almost undistinguishable: and presently, the heat rises rapidly, the mass fixes and becomes red hot. This is one of the best examples of the emission of latent heat. It takes place when the chemical combination is accomplished: and this required previous fluidity. But the temperature is too low for the compound being fluid: it therefore congeals, and latent heat emerges. If there be too much sulphur, this takes fire. This compound of iron and sulphur is a hard brittle substance, of a metallic appearance.

In consequence of this disposition to unite with sulphur, iron is often employed to separate sulphur from other metals, in the way of fusion. The iron, uniting with the sulphur, forms a very fusible compound, which flows uppermost: the other metal subsides to the bottom.

But besides the way by fusion, there is another way of applying sulphur and iron to one another, so as to make them act. It may be called the humid way. The iron is taken in filings, and the sulphur in powder: and they are mixed together with as much water as makes the mixture into a paste.

If this mixture be shut up closely, to prevent its communication with the atmosphere, the ingredients begin, after some hours, to act upon one another. The iron is corroded into a black mud or paste, in which the sulphur and it are somehow combined; for the yellow colour of the sulphur entirely disappears. This paste has a surprisingly strong attraction for vital air; and may be employed to absorb it when we wish to know what quantity of vital air is contained in atmospherical air, or other such mixtures of different airs. Dr. Scheele used it as a eudiometer, in a set of experiments which he continued for a whole year, to learn what proportion of vital air was contained in the atmosphere of Stockholm in all the different seasons and months of the year.

A drachm of flores sulphuris, mixed with two drachms of filings of iron, and as much water as will make it a thick gruel, must be put into a little dish, connected with a piece of cork, so as to float on water. If we invert upon this a jar capable of

holding 66 ounces of water, (nearly two quarts), all the oxygen contained in the atmospheric air, which fills this jar, will be absorbed by the mixture of iron and sulphur,...the water of the tub rising up into the jar, and occupying its place. When the filings are extremely fine and clean, and are mixed with the dry sulphur by grinding, and then a moderate quantity of water quickly mixed with these materials by kneading briskly, and this preparation put into a hot floating dish, it will absorb the vital air so rapidly that it will take fire. This may be ensured, by smearing with this magma some small twigs. This exposes a great surface, and soon heats.

If some pounds of this mixture be exposed to the atmospheric air, they will attract the vital air so fast from it, as to grow hot and to take fire. They grow hot also, although they be not exposed to the open air, if the quantity of them be so great as 50 pounds or more; for, in this case, there is so much air entangled in the paste in making it up, that the absorption of this air is enough to produce a considerable heat, and even to fire it.

After this absorption and heat are over, if we examine the remaining matter, we find the sulphur changed more or less into sulphuric acid, which remains combined with the iron, and forms with it a vitriolic compound, more or less perfect. It is evident, that the vitriolic compound is formed in consequence of the strong attraction, both of the sulphur and of the iron for the oxygenous principle, which they draw partly from the water, but principally from the air. By this principle the iron is slightly calcined, and the sulphur is changed, at least in part, into sulphuric acid. The decomposed water, when there is enough of it, gives inflammable air: and the air from which the oxygenous principle is attracted, gives out a great part of its latent heat or caloric, in the form of sensible heat, which heats the materials sometimes to such a degree as to make them take fire. When the materials are in large quantity, and covered up, or buried, so as to have little communication with the air, there is more water decomposed, and more inflammable air produced. When, on the contrary, the quantity of them is small, and they are confined with a quantity of air, they draw the oxy-

genous principle chiefly from that air, and decompound the whole air which the vessel contains.*

A similar change of sulphur happens in some kinds of pyrites, which are natural compounds of iron and sulphur. And the discovery of this has given origin to the art by which common vitriol, or the sulphat of iron, is prepared in large quantities, and at a cheap rate. I formerly observed, that the manner of preparing it, by dissolving iron in sulphuric acid, is only practised as a process in pharmacy, and the vitriol, or *sal martis*, so prepared, applied only to purposes of medicine; but that a much cheaper way of obtaining this compound has long been practised, to supply the consumption made of it in several arts. By this cheaper method, it is prepared chiefly from some particular kinds of pyrites, which, when exposed to the action of the air, and of humidity at the same time, undergo a change, by which the sulphur becomes sulphuric acid, and we get a vitriol, or sulphat of iron, in place of the pyrites, or compound of iron and sulphur. Humidity alone is not sufficient. The pyrites has not the power of decompounding water. Cramer says, he observed immense quantities of pyrites all along the English shores, especially about Harwich, which naturally lie in a bed at the depth of some feet below the surface of the sand. As long as they lie there, though they are constantly wet with sea water, they continue entire and quite insipid: but when thrown up to the air by the waves, they are crumbled down, and converted almost entirely into a heap of little crystals, in a fortnight. This is indeed the case every where, for the pyrites is always exposed to abundance of humidity in the bowels of the earth, but nevertheless retains its form until it is dug up and exposed.

This change, which the pyrites of iron is liable to undergo, is called *vitriolization*:...it is said to *vitriolize*.

It is proper to remark, however, that only particular kinds of pyrites are liable to it, not every kind. Some kinds, such as the cubical pyrites, common in slate, and some others, withstand

* Consult on this subject Mr. Lavoisier's Essays, published in 1777, where the whole procedure is analysed with great precision and distinctness. *Le Sage Elem. de Chymie*, i. 42.....Werner on the *Origin of Volcanoes*.....Hopfner's *Magazine of Natural History*.....Lemery, *Mem. Acad. Paris* 1700.

the action of air and humidity a long time without suffering a change: or if they are changed, it is very slowly, and only into a hard rust at their surface, but without affording vitriol.

The cause of this difference among the varieties of pyrites has not been discovered. I suspect that it depends upon the proportion of the sulphur to the iron; and that those which contain most sulphur, are most liable to vitriolization.

Process for Vitriol from Iron Pyrites.

The account which I have given you of the chemical procedure will naturally direct you to the proper methods of accelerating the operation. I have only to remark, that some kinds of pyrites require a preparation, by roasting in a heap with a small quantity of fuel. This is found to dispose the harder pyrites to a more rapid decomposition; probably opening their texture by the expulsion of some of their volatile ingredients.

The pyrites being thus in a proper state for vitriolization, the rest of the process is the same for all kinds. A piece of ground is chosen, having a very gentle declivity, just enough to make the water run in one direction. This is laid out in narrow quarters, like a kitchen garden,...the furrows which separate them having the direction of the slope. The ground between is covered with firm clay, well beaten, so as to be quite impervious to water. The surface of each quarter has a slope on each side toward the furrows. Another furrow is led across the lower extremities of those which separate the ridges: and this furrow terminates in a great cistern.

The pyrites, broken into small pieces, are spread on the quarters or ridges, and made up into beds about two feet thick. They effloresce: and the rains wash off the saline crystals. The solution trickles off into the gutters, which conduct it down the slope into the cross drain, and by it into the cistern. In very dry weather, it may even be necessary to sprinkle the pyrites on the ridges. As the solution is very weak, especially in the rainy seasons, it is frequently thrown again on the vitriol beds

by a forcing pump: and it comes off them still more impregnated with the salt, till at length it is fit for boiling.

For this purpose, it is pumped up into the boiling house, which is built over the cistern, and is reduced to a strength proper for crystallization, by boiling off the superfluous water. From the boilers the liquor goes into the vats or cisterns, where it is allowed to cool and to crystallize.

There are some pyrites which are so much disposed to vitrify, that heaps of them are liable to grow hot and take fire: and this has happened on different occasions to some kinds of pit-coal abounding with pyrites, and which had been collected together in large quantity. At Ayr, for example, an immense body of coal, built up for exportation, took fire: and in Dublin it happened to a large quantity of English coal, which had been provided by the corporation to prevent scarcity; and this happened in both cases after a heavy shower. Vessels loaded with such coal have unfortunately been set on fire sometimes in that way.

In many coal pits, the pyritical rubbish, which is mixed with the coal, and would spoil its sale, is picked out, and left below. When these pyrites have been accidentally in too large heaps, they have frequently taken fire, and have set fire to the coal works. George Agricola, who wrote in the 15th century, speaks of the fire in the coalwork at Dysart in Scotland as a very old thing. It is not yet extinguished. At Kilkerran, in Ayrshire, a very extensive coal-work has been burning now for fifty years. At Johnstown, near Paisley, a stratum near seventy feet thick was set on fire by the rubbish, and continued burning with incredible fury, having a great current of fresh air. In one place there was a face of coal red hot for near 100 yards, and the flame ascended through one of the pits to the height of above 100 feet. It was at last extinguished by drowning it. But whenever the air is admitted, it takes fire in a few days.

From such examples, some have endeavoured to account for hot springs, subterraneous fires, volcanoes, and earthquakes. They have even attempted to imitate some of these convulsions of the earth. Lemery was, I believe, the first who attempted this imitation. (*See Mem. Acad. Par.* 1700.) It has often been done since. The general process has been, to mix as large a

quantity as can be conveniently had of clean iron filings, with somewhat more of sulphur, and as much water as will make a firm paste, and to bury this in the earth, (first wrapping it up in a cloth) and ram the earth firmly above it. In a few hours it grows warm, and swells so as to raise the ground. Sulphurous steams make their way through the crevices, and sometimes flames appear. Rarely is there any explosion: but when this happens, the fire is vivid and brandishing,...and the heat and fire continue for sometime, if the quantity of materials has been great.

We cannot expect more,...we see the production of internal heat, sufficient for more violent operations: but other circumstances must concur. If water get in by a crevice into a cavern containing red hot materials, there seems no bound to the effects which it may produce.

The phosphorus of urine can also be combined in small quantity with iron, by melting the phosphoric acid with iron and charcoal dust. The compound is more fusible than iron, and is not decomposed but with great difficulty, which we should not expect of a substance so volatile and inflammable. It makes iron cold-short, that is, it will not bear hammering out when cold, but cracks all over.

Relation of Iron to other Metals.

Iron can be mixed with all the other metals, excepting lead and mercury. It shews a disposition to unite the most readily and strongly with arsenic, and with the regulus of antimony, and with gold. None of the mixtures of it with metals have been found useful, except perhaps manganese, which is supposed to improve iron: but its effect is not sufficiently ascertained by experiments.

Iron is, in general, much impaired in its most valuable qualities, cohesion, malleability, and toughness, by any metallic mixture. Arsenic in particular unites most readily, and adheres most obstinately; and makes it red short, that is, apt to crack under the hammer while forging, and even to fall in pieces.

Ores of Iron.

Iron is seldom found pure and metallic ; but examples of this however have occurred. A mass of 1600 pounds weight was found in Siberia. Its interstices were all filled up with glass, of a beautiful bright green, and so friable as not to cut the fingers. This circumstance shews that it has been the effect of fire, and that the glass has been quenched in water while yet red hot. Another mass, much larger, has been found in Paraguay. Such masses are said to be not uncommon in Senegal. (*See Note 54. at the end of the Volume.*) Mr. Margraaf has found malleable iron in strings at Eibenstock in Saxony. These are the only known instances ; but the ores of this useful metal are plentiful in all parts of the world. And besides, iron is found mixed with many of the other productions of nature, such as the ores of other metals, coloured clays, and boles. Indeed few earths are free from it. The garnet, the emerald, the ruby, topaz, sapphire, and amethyst, appear to derive their colours from it. It is found even in the ashes of vegetable and animal substances,in the blood, milk, flesh, and hair. It has been found in plants which have been raised from a seed in distilled water. Some fossils containing iron are of great use, although not as ores of iron ; such as emery for the lapidary ; hæmatites for the burnishers ; the red, yellow, and blue ochres for the painters ; and the loadstone for the navigators.

As the ores of iron are very common, only the richest or most profitable are wrought. In this country, the minerals melted to extract iron from them are distinguished into three kinds.

1st, Iron ores found in veins.

2d, Iron-stones, interspersed through strata, or forming thin strata among others.

3d, Bog ores, intimately blended with clay, and with the remains of animal and vegetable substances ; not mixed, but in many cases chemically combined.

All these are in general oxyds of iron, in different states of oxydation : and some are combined with fixed air, and with small quantities of some of the earths. When they are much

oxydated, and nearly pure, or with very little of the earthy substances combined with them, they have a dull and deep red colour, which is the natural colour of the oxyd of iron highly oxydated. Or if some fixed air be united with them at the same time, they are yellowish: these are the spathose ores of iron, or carbonats of iron. If, on the contrary, they contain the iron but little oxydated, they are grey or black, or approach by their colour to iron itself. They are also variously crystallized; of these the bloodstone, or hæmatites, is the most beautiful. Their appearance is also very much affected by the mode of their concretion, and by the admixture of earthy matter. White ores and micaceous ores often contain manganese, and are thought to yield excellent iron.

The hard pyrites, though it contains much iron, is not treated as such: It is considered only as an ore of sulphur.

To extract the iron, the minerals are first roasted. This operation appears to be necessary or useful, in extracting iron from many of the minerals from which it is obtained. It is probably useful by expelling sulphur or sulphuric acid.

The next operation is to reduce the roasted ore to a metallic state, or metallize it completely.

This is done in a high furnace, shaped internally somewhat like two round crucibles joined by their mouths, the uppermost without a bottom. The bottom of the furnace is hollow, having on one side a hole through which the blast of a bellows can be directed a few inches above the bottom. On the other side is a larger hole, through which the melted metal can run entirely off. A heap of brushwood is thrown into the furnace. It is kindled, and immediately covered with charcoal or coak: and then baskets of ore and fuel are added till the furnace is filled,...the bellows being worked all the while. The tap-hole of the furnace is shut up with clay. Every thing being loose and open, the flame is forced by the blast of the bellows through the whole furnace, and a violent heat is raised all over it. As the fuel consumes, the matters subside; and baskets of ore and fuel are repeatedly thrown in to fill up the furnace. The earthy matters and ore are melted by the intense heat into a glass. And since the burning fuel is every where in contact with the

ore, and the coal has a much greater attraction for the oxygen than the iron has, the metal is reduced, and sinks to the bottom of the furnace under the melted glass produced by the fluxing of the earths. The metal is now defended from the action of the bellows. When the workman thinks that there is enough collected, he makes a hole in the clay with the tap-iron: and the metal runs out, and is followed by the glass or slag.

A considerable quantity of limestone is mixed with the ore in this operation; seldom less than one-sixth of the ore. Its use is partly to promote the fusion of the earthy matters mixed with the metalline oxyd, and partly to combine with the sulphuric and sulphurous acid; by which means it is carried off in a vaporous form, but takes with it some iron. It is thought that a better quality of iron is obtained by the large use of lime, even when not required as a mere flux.

It is also found, in all cases, of great advantage to the quality of the iron to use a very great quantity of fuel. This, unquestionably, produces a more complete absorption of the oxygen and reduction of the metal. A great allowance of fuel brings more metal from the same ore, and makes it more fusible after repeated meltings. It is very grey, shewing shining black facets, and talky-like matter, and is softer and easier cut than white cast-iron which has been made with less fuel. But the room occupied by the fuel causes the furnace to produce less iron per day; while the blast or quantity of air consumed remains the same. Therefore, this iron is much more costly. In the Scotch furnaces, the iron-stone requires between three and four times its weight of soft pit-coal: and each ton of iron produced requires the consumption of 672,000 cubic feet of common air. Some fuels, particularly blind-coal, require much less. Much more is required in summer than in winter.

The quality of the iron is affected also by the nature of the fuel. Wood charcoal is best for producing iron to be refined and made into bars. Charred pit-coal is best for iron to be employed in cast work.

When first melted down from the ore in the great furnaces, the metal is in the state called pig-iron, or pot metal; and is

fit for cast work ; in which state it is perfectly fusible, but is either quite inflexible and brittle, or has very little flexibility and toughness. It is useful, however, for many purposes. In consequence of its fusibility, it can be cast in moulds, to form large massy pieces, and instruments of a very great size, which are thus formed at a far less expence than if it were necessary to forge them ; besides that some, on account of their large size, could not be forged. But fusible iron is unfit for anchors, and other such instruments, which must be exceedingly strong and tough.

I should observe, in this place, that the cast iron obtained by this process appears in three states, which are very distinguishable, both in appearance and qualities, according to the manner in which it has been manufactured.

1st, WHITE CAST-IRON, extremely hard and brittle. It cannot be filed, or bored, or repaired in any way, nor bend. It cannot bear very sudden changes of temperature, without cracking. Its structure is crystallized, with very small brilliant facets.

2d, GREY CAST-IRON, of a granulated texture, and often plated, but of an unequal dull colour. It is much more cohesive than the former ; and is therefore employed for artillery. It is also softer, and may be cut and bored, and even turned in a lathe.

3d, BLACK CAST-IRON, the most unequal in its texture, the most fusible, and therefore often mixed with the white to make it stand a repeated melting. It is less tenacious than either of the former.

The first seems to contain much unreduced oxyd, and even some earthy matters, which vitrify along with it. These are entangled among the truly metallic parts ; and thus defend them from the action of the air. The second kind has little unreduced oxyd, or earthy matter, having been prepared with more fuel and greater heat : but there is more of the inflammable matter of the fuel combined with it. The last also contains much of this, and derives other varieties from the nature of the ores. It makes the best refined or malleable iron.

Iron is changed from this fusible and rigid state into tough and malleable iron, in the forge, or finery as it is

colled, and by an operation which is considered as a refinement of it.

Until lately, the only manner of performing this operation was by heating two or three hundred weights of it at once, in a hollow forge, in which the iron was covered with a fire of charcoal, and lay in a bed of charcoal dust and ashes until it just melted, with no more heat than what was barely sufficient; and it was kept in this heat for some time,...the wind of the bellows being directed through the charcoal, so as to have some effect on the surface of the metal; and being stirred now and then, it was taken out a toughish cavernous mass, and was compacted by hammering.

But within these few years, another process was contrived by a Mr. Cort, which admits of an immediate inspection and examination of all the phenomena; the metal not being covered with the fuel, but exposed to the view of the operator and observer.

Here the iron is melted in a reverberatory furnace: and a strong flame is kept blowing over it, so as to keep it in a most intense heat. It is all the while stirred about with a rake, so as to bring every part of it to the surface in succession. By this treatment certain impurities of the iron are dissipated in a way that we do not yet understand. The fact is, that it gets into a particular state, which is indicated without any danger of mistake, by the iron becoming thick like gruel, swelling up a little, and the surface of it all at once becoming of a dazzling brightness, by a low flame which gleams upon it. It is now said to be *brought into nature*.

When the iron is thus *brought into nature*, that is, has lost its fusibility, and is become malleable, it is collected into two masses in the *laboratorium* of the furnace, by raking it together, and compacting it with the strokes of an iron club or mace. These masses are called *loops*. They are very porous and spongy, and contain a great deal of scoriæ, or semi-vitrified matter, mixed with the iron. The heat to which they are exposed is then increased for a short time, until these scoriæ are completely melted, at which time the loop is taken out, and immediately exposed to the strokes of a large and heavy hammer, wrought by a water wheel or

steam engine. This compresses the mass ; unites the parts, of it more closely ; and forces out the greater part of the vitrified matter, or *finery cinder*, as it is called, out of its pores. The mass is turned under the hammer, until it is formed into a short and thick prism or cylinder called a *bloom*, the parts of which are not yet so closely united as they ought. But by heating it again, and subjecting it again to the great hammer, or passing it between rollers contrived for this purpose, the parts of it are made to enter into close cohesion, the liquid dross completely squeezed out of its pores, while it is at the same time forged into bars of different kinds.

The iron made by this process, from very ordinary iron, such as was known to yield bad bar iron, proved equal to the best Swedish iron. Very severe trials were made by Government, as it was recommended for the use of the navy, for anchors, bolts, straps of blocks, and other uses, where toughness was an indispensable requisite. But, to make bad iron so eminently good, required much labour and expence. Cast iron, which yielded better bar iron by the usual processes, was amenable to the same degree of fineness with much less trouble. I mention this circumstance, to shew that the process is general, and depends on principle.

By this process, the expence of wood charcoal, which is a very dear fuel in this country, is saved ; the whole operation being performed by the flame and heat of pit-coal.

By whatever process fusible iron is refined to the state of tough iron, a considerable part of it (one-third commonly) is scorified or calcined, forming a fusible calx or oxyd, called FINERY CINDER. It is exactly similar in its appearance to the fusible oxyd formed from iron when it is burnt in vital air. The production of this finery cinder is absolutely necessary. And the skilful workmen say, that for the right performance of this process, it is necessary that the refining iron be well soaked, and mixed to a certain degree with this finery cinder ; for which reason, although they let some of this cinder run out at a tap-hole of the furnace or forge, when it accumulates too much, they never let it all run out,

but retain a proper quantity in the furnace or forge all the time they are working.

But it is also certain that the iron loses a quantity of inflammable matter, which is contained in it while in its hard and brittle and fusible state.

When we try to dissolve fusible iron in acids, we find it more difficult to dissolve it, and there is an incomparably greater quantity of plumbago left from it than from tough iron. You know that plumbago is principally composed of carbon, or carbonaceous matter; but there is, besides, often some sulphur or some phosphorus. The change of fusible into malleable iron appears, therefore, to depend chiefly on the destruction of the plumbago, or of the greater part of it. And it is easy to shew in what manner this happens in the refinement of iron. Dr. Beddoes has endeavoured to explain how it happens in Mr. Cort's process: and he has explained it in some measure, but assumes a principle which I cannot admit.

The principle assumed by Dr. Beddoes and the French chemists, is, that the unrefined fusible iron, besides containing a quantity of carbon, also contains iron in the state of an oxyd; and that the oxygen of this ill-reduced iron acts on the carbon, and produces the increase of heat, and the intumescence, or fermentation, and the eruption of elastic fluid and of flame.

But it always appears to me inconceivable, that there should be present in fusible iron, at the same time while it flows white hot from the great furnace, both an abundance of carbon and an oxyd of iron, without acting on one another originally, especially in the grey iron, which most abounds in carbon.

There is no occasion for having recourse to so unwarrantable a supposition. It is evident that the effect of a great part of Mr. Cort's process is to calcine a part of the iron in the first place. While the workman is busily employed in stirring it over from one side of its bed to the other, separating it into small parts, and mixing the whole carefully together, a quantity of the iron (to which the air is admitted all the while) must be calcined or oxydated. He then increases the heat a little, to make the oxygen of this calcined iron act on the carbon of the uncalcined. This increases the heat in the iron, and

produces the fermentation, or formation of carbonic acid gas, which, while it rises, carries some carbon with it,...and hence the blue flame. The nicety of this operation depends on knowing how far to carry the calcination of part of the iron, that there may be enough of oxygen to consume the whole of the carbon. If more iron than enough be calcined, it is so much lost.

Such a persuasion suggested to Mr. Reaumur a project to soften or give toughness to cast iron by cementation. He conceived iron to differ from other metals by combining with much more inflammable substances than was necessary for its ductile form, and expected to absorb or consume this by proper substances. He therefore cemented cast iron with earthy powders; and after the cementation is carried a certain length, the iron yields to the file, if slowly cooled, but if tempered, is quite hard. It has some malleability when red hot, but none when cold. If it be strongly heated, it flies to pieces under the hammer. Thus it plainly resembles steel. Continuing the cementation longer, it becomes now so soft as to be easily cut, filed, bent, or forged, and does not become much harder by temper. In proportion as it becomes soft, it loses its fusibility; and the internal parts can be melted out; so that in every respect it is similar to forged iron, only it is not so compact or solid. All these changes seem accountable by a gradual exhalation of the carburet included in the crude iron. This may be assisted in Reaumur's processes by the cementing matters, either by their absorbing this matter as it exhales or comes to the surface, or perhaps diminishing the attraction, by presenting to the iron or the carbon some vapour for which they have some attraction. But we do not know any matters that are much preferable to others which are not obviously improper. Though Mr. Reaumur did not succeed in establishing such an art in France, it is now practised in Britain.

The very best kinds of refined, or bar iron, are very strong and tough when cold; and bear to be bent backwards and forwards very much before they break: and they are also very malleable when hot. Sweden is remarkable for producing iron, from some of its ores, of this very best quality. But the greater number of iron ores do not produce iron so good, though it be good enough for common uses.

The blacksmiths distinguish the common kinds of iron into two varieties, of which however there are many degrees. To these two varieties they give the names of red-short iron and cold-short iron. The red-short is tough and flexible when cold, and works very well when strongly heated: but if under-heated, it is brittle under the hammer. And as there are many varieties, the smiths make trials at first to learn how the iron is best wrought. The cold-short iron, if cooled slowly after being heated, proves quite brittle while cold, especially thick bars of it; and acquires flexibility by being plunged red hot into cold water, but is always deficient in it. In its brittle state it breaks so as to shew facets or plates remarkably large in the surfaces of the fracture.

Professor Bergmann made a great number of experiments to learn the causes of these different qualities of iron; and thought he had discovered the cause of cold-shortness, ascribing it to the presence of a metal which he called *siderum*: but this has been found to be a mistake. Mayer shewed that it is a phosphat of iron. Mr. Cort's process removes or prevents this bad quality.

When a piece of tough hammered iron is broken by bending, it is found to be fibrous. But if the same piece be kept red hot for some time, and again broken, the fibrous appearance is almost gone. It would seem that it acquires it by the action of the hammer; and that iron consists of malleable infusible stuff, mixed with a remainder of fusible iron. Such a mass, when heated red hot, must work under the hammer, like a paste in kneading, the fluid part being squeezed along between the ductile parts like so much grease. Perhaps this is the source of that shining or glowing skin which it acquires in a welding heat, which enables two pieces to be struck together by the force of blows.

I have now described the progress of iron from the ore to that state of this metal which appears to be the purest and most perfect state of it, and in which it is called tough iron, or bar iron. I must, in the next place, give some account of STEEL, which is iron in a different state, and possessed of properties by which it is much better adapted to serve some of our purposes than tough iron is.

Steel is refined iron, intimately combined with a small quantity of pure carbonaceous matter, or the carbon of the French chemists.

Slender bars of iron are put into a crucible, and covered with charcoal dust rammed close round them. The crucible is luted, and set in a furnace, where it is exposed to a strong red heat for some hours. When the iron is taken out, its surface is frequently found rough and blistered. This I believe is owing to the pushing the operation a little too far. It is now converted into steel, and considerably increased in weight.

At Newcastle, and other places in England, they have furnaces for this purpose, in which large quantities are made. These have the form of a large oven or arch, terminating in a vent at the top. The floor of this oven is flat and level. Immediately under the middle of this floor there is a long arched fire-place with grates, which runs quite across from the one side to the other, so as to have two doors for putting in fuel from the outside of the building. A number of vents or flues pass from the fire-place to different parts of the floor of the oven, and throw up their flame into it, so as to heat all parts of it equally. In the oven itself there are two large and long cases, or boxes, built of a good fire-stone: and in these boxes the bars of iron are regularly stratified with charcoal dust, ten or twelve tons of iron at once, and all is covered with bed-sand. The heat is continued five or six days and nights without intermission. And it requires as long a time for the furnace to cool again, before the steel can be taken out, and the boxes filled with fresh bars of iron.

This process is a cementation, and the carbonaceous matter must be introduced into the iron in the form of heavy inflammable air. You must recollect the experiment of Mr. Morveau, in which he exposed a diamond to intense heat, shut up in a small cavity in tough iron. The diamond vanished, and the iron around it was converted into steel. These facts shew very plainly what happens. The charcoal, or carbon in substance, combines with the metal.

Accordingly, a chemical analysis of steel shews this completely, by giving us the carbon again in some other combin-

ation, as will appear in a variety of ways. It appears by the results of its exposure to great heats. It is gradually deprived of its qualities of steel by long continued red heat: and it emits carbonaceous matter, if not carbonic acid. A fine steel wire burns with amazing brilliancy in vital air, and produces both fixed air and inflammable air. This carbonaceous matter is discoverable in steel by the action of acids, particularly aquafortis. When steel is dissolved in an acid, we obtain much more plumbago from it than from the worst kinds of tough iron, although not so much as from the grey cast iron. If this experiment be performed with sulphuric or muriatic acids, the difference is not so remarkable, but not less real. In these acids, the solution proceeds chiefly, or primarily, from the decomposition of the water, and inflammable or pure hydrogenous gas is produced. This combines with part of the carbon in its nascent state; and composes the heavy inflammable air, which is really obtained in the solution of steel in sulphuric acid; whereas pure tough iron gives us hydrogenous gas.

With aquafortis, the produce of plumbago is much more considerable, when the process is carefully managed. The nature of it is also more distinctly seen. And I am persuaded that iron constitutes an ingredient of it; and that the French chemists are right when they call it a *carburet of iron*; though others say that the iron exists in it only accidentally. In the trials I have made, its quantity or proportion is too constant to be accidental.

Steel, therefore, appears to be pure iron combined with inflammable matter. By pure iron, I mean the metal completely reduced, that is, cleared of all oxygen, and of all earthy and combustible matter; in which respect it differs from cast iron, which undoubtedly contains much earthy matter, united with an oxyd of iron in the form of glass, which is entangled in the pores, and cannot be squeezed out without a vast deal of hammering and labour. The cast iron resembles the steel in this, that, like it, it contains much inflammable matter, which it acquired from the fuel, and which remains defended from the action of the air by the very fluidity which it occasions, and which is expelled only by stirring, and presenting a great surface for a long time to the action of the air.

This notion is confirmed by the fact, that a slender rod of iron, plunged into white or grey cast iron in fusion, is converted into steel.*

The qualities of steel, by which it differs from iron, are,

1. It is more fusible. Tough iron cannot be melted in the most violent fires of common furnaces. It only becomes very soft, but never fluid. But steel can be melted perfectly in crucibles, if exposed to the most violent heats of common furnaces.

2. In its solid state, steel is more rigid and hard than iron; nor can it be so much softened by heat, without losing its tenacity and flying in pieces under the hammer. It requires therefore more care and attention to forge it well than to forge iron.

3. Steel is much more readily broken by bending it than tough iron. It does not bear to be so much bent backwards and forwards. When a bar of it is broken, the surface of the fracture is quite different from that of iron. A bar of tough iron shews by its fracture that it is composed of fibres, the surface of the fracture being very rough, with the ragged ends of them. But steel, when broken, shews that it is composed of very small grains, of a plated structure; and presents a whitish grey surface, much more plain than that of the broken iron.

The most useful qualities by which steel excels iron, are the strong cohesion of its parts,† and the extraordinary hardness it acquires when made red hot, and very suddenly cooled. It is thus made so hard as not only to cut iron with ease, but steel itself in its softer state.

This excessive hardness is attended with perfect rigidity and inflexibility, which makes such hard steel in some measure brittle. Files, which are hardened to this degree, can be broken by a fall. But the artists temper this hardness more or less, to fit the steel for different purposes.

* Should not finery cinder, and all pure oxyds of iron, when reduced by charcoal and proper fluxes, in the nice experiments of the laboratory, be steel, and not iron? Are they always so? I think not.....EDITOR.

† A steel wire of one-tenth of an inch in diameter, will just break when loaded with 900 pounds, if properly tempered, and more than 700, if soft....
EDITOR.

This is done by heating the hard steel again. If its surface be made clean by grinding or polishing, then, when it is heated again, it will acquire a straw colour, which will gradually proceed to a full gold colour, with ruddy purple streaks, which afterwards become full purple, violet, and deep blue. These colours direct the artist in what state he shall arrest the temper, by dipping the steel into water or grease. The first appearance of yellow fits it for the edges of chizels and punches, which are to be employed upon iron itself. The full gold colour, or the beginning of purple, fits it for chizels which are to be employed on the softer metals. A little more of the purple fits it for common edge tools. And the violet or blue fits it for watch springs. When clouds of a dingy yellow appear among this blue, it is becoming too soft.

It would be a very desirable thing to combine this extreme hardness of steel with the toughness and tenacity of iron. The only way we can do this is by welding them together. It is thus that our edge tools are made. A bit of steel is welded to the iron, on that side of the plate or bar which is to be worked into an edge.

There is another way, which is peculiarly serviceable on particular occasions. We can convert the surface of any piece of iron into steel by cementation, which we can stop before it penetrate so far as to make the whole become steel, and brittle. This is called CASE-HARDENING. The piece of work, when very nearly finished, is covered with a paste made of charcoal or other combustible matters. Long experience has produced an universal preference of animal charcoals, or rather the crude substances. Horn or hoofs, chopped hair, bone shavings, and some other fanciful ingredients are made into a paste. The iron is covered with it, and the whole wrapped up in clay. This is first dried and hardened before the fire, and then put into the forge, and kept of a low red heat for an hour or two. When taken out, it is superficially steeled. In this manner are almost all the parts of gun locks treated. Besides the superficial hardness acquired by it, it is well known that they have incomparably less friction than when only iron: and they are much less liable to rusting.

The extreme hardness appears to me to depend on the extrication of latent heat. And the abatement of this hardness by the temper seems to be produced by the restoration of a part of that heat.

With respect to the qualities of steel in mixture, they are precisely the same as those of iron, except the small differences proceeding from the excess of inflammable matter which steel contains. It is more fusible, more inflammable, not quite so readily rusted or dissolved: and it can be reduced to iron again, by abstracting, or otherwise separating this inflammable matter.

Besides the steel produced from bar iron by cementation, we sometimes have it directly from the ore. The spathose ores in Corinthia afford it at the first. The cast metal from them is melted in a pot. By throwing a little water on it, a plate is congealed on the surface, and lifted off: and this is repeated till all is expended. These plates are then melted again, and kept in a melting heat for a long time, which requires a continual increase of heat; and they are found to be steel. An ore in the island of Elba, and some ores in Barbary, have the same qualities with the German ores now mentioned. We do not well know the various processes, many of which seem very fanciful.

The finest and best kind of steel is called *cast steel*: and the process for preparing it was invented in England. All fine instruments and razors are now made of it. (*See Note 55. at the end of the Volume.*)

I conclude this article by referring you to Fourcroy, who has treated this important subject with the greatest distinctness, and a very fair and copious narration of facts; so that I think a judicious chemist will find himself quite independent of all his theories, which seem but ill supported.

Medicinal Virtues of Iron.

This metal has always been esteemed as a valuable article of the materia medica; and furnishes, in its preparations, medicines of great efficacy. There seems to be no foundation,

however, for the opinion which chemists entertained with regard to it, that, according as it is differently prepared, it acquires powers over the body of a different, and almost opposite nature.

Iron itself, and most of its preparations, taken into the body, has often a very manifest constringing effect, which is still more remarkable in several of its preparations, when applied externally, in cases of hemorrhage from wounds, &c. They act with some degree of acrimony and pain, in contracting the vessels from which the hemorrhage proceeds. They have often had this effect, when given in cases where it was not practicable, or not eligible, to apply a remedy directly to the part itself from which the hemorrhage proceeded; as in dysentery, hemorrhoids, too profuse flow of the menses, lochiæ, &c. These observations first established the character of iron as an astringent medicine. But its effects upon other occasions seemed to be of a different kind. Both the metal itself in substance, and all its preparations, were long noted as some of the most powerful remedies by which the menstrual evacuation may be restored, after it is suppressed; and for promoting the motion of fluids through the whole body. The saline preparations of iron, if exhibited along with a considerable quantity of water, increase very sensibly the evacuations in the form of urine, and of perspiration; and, if given in a greater dose, have a quick effect in exciting discharge from the guts. On account of these effects, the metal was also supposed to be endued with an aperient or deobstruent virtue, attributed to one of the ingredients in its composition, viz. the phlogiston; while the astringent virtue was referred to another,...the earth. And the chemists endeavoured, by a variety of processes, to separate them, or obtain some medicines possessed only of the aperient quality, and others only astringent. And some even imagined that they performed this in a certain degree; so that we still find, in some dispensatories, preparations distinguished by the titles of aperient or astringent. It is, indeed, certain that some of the preparations contain a larger proportion of the inflammable metal than others. But it appears from the consent of practical physicians on the subject, that this only renders the medicine more or less efficacious,...those containing the greatest quantity of this subtle

principle producing their effects more sensibly and certainly, but not differing in the manner of their operation from others.

The powers by which iron produces its effects are, in the first place, its astringency; or constricting virtue, a power of bracing the fibres over the whole body, diminishing in some degree the cavities of the vessels, and increasing the force wherewith they compress the fluids. Secondly, a powerful stimulus, friendly to life. By this it excites or promotes circulation, and all those motions in the body by which the alimentary parts are converted into good fluids, and the fluids preserved in a sound healthy state; and by which all secretions, both of recrementsitious and useful fluids, and all absorptions, are performed in different parts of the body. By this last property, iron differs from lead, which, together with astringency, shews a power rather of diminishing and deadening motion; and therefore is a much more powerful, though dangerous astringent. The astringent quality of the preparations of iron shews itself, by the taste of acerbity, which draws the mouth together, and by Dr. Hale's experiments with Chalybeate water. Their stimulating effects become sensible, if a large quantity of them be taken: they prove purgative, or even emetic, with a good deal of heat and disturbance. These effects shew, that when applied in considerable quantity to the nerves of the stomach and guts, they not only stimulate these, so as to produce a considerable increase of the secretions performed in those parts, but also excite a motion by which they are expelled. Their stimulating effects are likewise extremely evident over the whole system, when used in smaller quantity, so as not to produce disturbance in the stomach and guts. This stimulus is shewn by the warmth it diffuses over the whole body of the person who uses it, by giving a fresher colour to the skin, by the vigour and alacrity with which it inspires, in consequence of exciting a more brisk circulation. Physicians have doubted whether this action of iron proceeded from its entering the lacteals, and being mixed with the blood; because they observed that persons put under a course of such medicines very evidently void a considerable quantity of ochre, or calx, in the fæces. And, indeed, it is certain that the stimulus and constriction with which it affects the stomach must have immediate effect on the whole system,

on account of the remarkable sympathy daily observed between the nerves of the stomach and those of every other part almost of the body. But it is very probable, too, that some part enters the blood; because, although salts obtained from iron readily deposit a considerable quantity of ochre, it is not found that they can be entirely resolved in this manner. But in whatever way it acts, it is certain that a very quick change is wrought in the blood and circulation. The belly is, indeed, often bound in some measure: and the costiveness is produced, probably by quick absorption of the thinner parts of the food; but it is easily obviated by a small dose of rhubarb.

Upon account of these two qualities, iron and its preparations are among the most powerful remedies in weakness and laxity of the solids, and in watery disposition and poverty of the fluids, together with all diseases depending upon such a state of the body,....such as disposition to dropsy, and anasarca, or watery swelling, fluor albus, gleet, hysterical and hypocondriacal diseases, indigestion, diabetes, diarrhœa, and the too copious flow of the menstrual flux, when these proceed simply from a weakness and relaxation of the solids. In the chlorosis, it not only removes the languor, but restores the proper flow of the menses, by the stoppage of which this disease is either produced, or very much increased.

In autumnal intermittent fevers, when obstinate, and the body much wasted, it prepares for bark.

The preparations from iron are not adviseable, if the humours are considerably acrid, or when there are appearances of a putrid tendency. In such cases the nervous system is generally too irritable.

When the vessels are very full, iron medicines are hazardous, for the same reasons; and indeed it is always a proper precaution to take off some blood before a course of them.

In persons of strong and rigid fibres, and those subject to violent cramps, these medicines have often left sensible effects, in a disposition to these complaints.

In ulcerated lungs, and old and obstinate obstructions of the viscera, they are serviceable: and it is always proper to give them in small doses, and continue them some time.

- The most certain preparations are, *limatura ferri*,....*ferrum saccharatum*,....*crocus martis aperiens*,....*crocus martis astringens*,....*tincturæ martis*,....*sal martis*,....*flores martiales*.

GENUS IV.....MERCURY.

MERCURY is distinguished by being always fluid, and being by far the most volatile of all metallic substances. And these two qualities have laid some chemists under difficulties and doubts with respect to its proper rank among the metals. They made it a question whether it ought to be called a metal or semi-metal: and many have thought it could not properly come under either one or other denomination. But there is no reason to doubt that it is a metal. All the metals are fusible, or capable of fluidity, and volatile too, as well as it: and it differs from them, only in being more fusible, and volatile than any of them. We know now that it becomes solid, and proves very malleable, when cooled to a sufficient degree, viz.....40° of Fahrenheit's thermometer.

Chemists have given much of their attention to mercury, partly with alchemical views, and partly with a view to medicine. The alchemists probably expected success in their attempts upon it, on account of its great weight, by which it approaches more nearly to gold than the other metals then known, ...its specific gravity being 13,568*. And it became very much the object of pharmaceutical chemistry, soon after it was discovered to be a specific for the venereal disease, and before the best manner of applying it in the cure of that distemper was well understood. Its action on the human body, as it was employed at first, was attended with great inconveniences, and permanent injury, and even fatal consequences. It was thrown in hastily, and in great quantities, until it brought on a plentiful salivation, which was so violent, that it kept the patient in misery so long as it lasted. And moreover, the mercury, when employed in this manner, is liable to stimulate some other secretory organs beside the salivary glands, with a degree of violence that is not without danger.

The chemists imagined that these troublesome effects depended upon some noxious corrosive principle in the composition

* A cubic foot weighs 13,568 ounces avoirdupois, or 848 pounds.

of mercury ; and therefore tried innumerable processes with it, and changed it into a thousand forms, to separate, if possible, the noxious corrosive parts of it, and increase the medicinal powers of the rest. But the opinion upon which they proceeded appears to have been erroneous : and their labour has been in a great measure lost. Many of their preparations, it is true, are useful, and applicable to particular purposes for which crude mercury is not adapted ; and in several, they reduced it to the most efficacious forms : but in none of them have they taken away its power to produce noxious effects. These are only to be avoided by attention and skill in the management of it. When employed in the venereal disease, it never should be thrown in so hastily as to produce a great salivation, by which it will run out of the body again as fast as it is thrown in. We generally give it in such quantities as to bring on a slight spitting and affection of the gums ; for unless this sign of its action can be perceived, we cannot be sure that its powers are employed : but it never should be made to act with greater violence. And we must be careful that it do not excite other evacuations, and run off by them. We must be also careful to remove or obviate any disposition to inflammation, which may appear by inflammation actually present, or by a fulness and hardness of the pulse. The first impression of the mercury always increases the inflammatory disposition : and unfortunate consequences often follow. The fortunate use and effects of mercury, therefore, depend more on the judicious management of it, than on its having been prepared by elaborate processes. At least, if we consult experienced practitioners, who know more of diseases than of chemistry, the most will give it as their opinion, that the plain pill or ointment are equal, for the cure of the venereal disease, to all other preparations. It is necessary, however, to make it undergo at least the process of *trituration*, and that with the greatest care, and in the most perfect manner, that the parts of it may be divided and attenuated, and that very subtilely, to make it act certainly upon the human body. When thrown in undivided, it runs through the intestines, and produces no effect, or very little, and very uncertain. It was the fashion, about fifty years ago, to take mercury in this manner,

from an opinion that it had extraordinary good effects, by virtue of a spirit, or effluvium, that was supposed to be extracted from it by the intestines, though no part of the mercury itself, or none of its grosser parts, entered the blood. It happened, however, in some cases, that even the crude mercury, thus given, brought on a salivation. But from its having produced this effect in a few cases only, there is reason to believe that it had lodged in the intestines, and was divided by their motion.

When we desire to give it with certainty of its producing an effect, and of the effect being proportional to the quantity thrown in, we must take care that it be prepared at least by the most careful division or separation of its particles from one another. One way of doing this is, by rubbing it long and patiently with viscid and other substances, which, by interposing themselves between the divided parts, hinder them from readily joining again. The substances suitable to this intention, are axunge, turpentine, and other balsams; mucilages, that is, mixtures of gummy substances with water: viscid sweets, as honey; even earthy powders sometimes, and water. Boerhaave first produced a black powder from mercury by agitating it in water; and Dr. Priestley has made many experiments upon this black powder and its production, and has discovered a number of curious particulars relating to it. You will see them described in the volumes which he has published, to which I refer you.

In whatever way mercury is thus divided, it acquires a small degree of solubility in the animal humours, and affects the tongue with a sensation of a particular nauseous taste, which shews that some of it is dissolved by the saliva. This power in our fluids to dissolve mercury probably depends upon the ammoniacal salt they contain; for common sal ammoniac plainly acts upon mercury when rubbed with it.

But it is also believed by many, that water, unassisted with any other matter, has some power to dissolve it, or to receive from it some medicinal efficacy. Gaubius, the French physicians, and many others, aver, that when it is boiled in water, it gives to the water the power of killing worms in the intestines of animals. Such water has been recommended by many as an effectual and safe anthelmintic. And this power it can only

derive from some small part of the mercury dissolved in it; though, if there be any, it must be exceeding small, as the mercury does not suffer a perceptible loss. The water certainly acquires what is called the metallic taste, not sensible at first, but sufficiently so in a few hours, and for a long while after.

When mercury is exposed to the action of heat, it soon begins to evaporate and boil like water. This happens when the mercury is heated to about 600° of Fahrenheit's thermometer.*

The vapour of it, when mixed with air, does not immediately calcine, as the vapour of some of the other volatile metals does. If immediately condensed, it returns again to the form of mercury. And this metal may be distilled in a retort, without suffering any material change. We can therefore purify it by this process from admixture with other metals, most of which it is capable of dissolving or mixing with. And it happens to be mixed with them sometimes, either by accident or by design, in different operations in which it is employed. When thus mixed, it is called foul or impure mercury. The signs of this foulness are,

1st, A flat surface in the phial, not convex like that of pure quicksilver, the convexity of which shews that it has more cohesive attraction than the impure.

2dly, The formation of a pellicle on its surface, in consequence of which a sort of wrinkles are formed on it in moving it gently. This pellicle, adhering to the surface of the vessel, leaves a train behind the mercury, when it is made to run from one part of the glass to another.

3dly, The formation of a black powder upon the surface of mercury, when it is shaken in a phial with good or respirable air, and still more quickly with vital air.

* It evaporates in temperatures far below this, when the pressure of the atmosphere is removed. If a well filled barometer be kept near a window in a warm room, the part of the tube above the column of mercury becomes dim within, on the side next the window. When this is viewed through a magnifying glass, it will be seen owing to small spherical drops of mercury, which the coolness of this side of the tube has condensed. If the barometer be inclined, so as to make the mercury reach the top of the tube, it will lick them all up, and the tube becomes quite clear....EDITOR.

It sometimes has the appearance of a pellicle on its surface from dust or greasiness, or dampness adhering to it. In this case, straining it through thick linen or leather, or passing it through a paper cone, will make it clean. But if it become foul again, there is reason to conclude, that other metals are the cause of its foulness; and it must be made clean. There are various methods of doing this. Simple agitation, in contact with atmospheric air, will produce this effect. It is a general fact, that all mixtures of metals attract oxygen more strongly than the metals when separate. This is remarkably the case with mercury. Agitation with air quickly produces a black powder, which, when separated by filtration and expression, is found to be chiefly a calx of the other metals: and we can obtain the mercury perfectly pure by this process. But some of the mercury is entangled in the powder, and some is really oxydated. It is not, therefore, the best process for purifying mercury: and it is but a lately discovered one. The usual process has been by distillation. Iron filings are added, and with good effect. Their usefulness is commonly imputed to their attraction for the metallic impurities. But lead is the most common impurity; and iron has no attraction for it. Others suppose that they serve only to prevent any drops of the boiling mercury from starting over into the neck of the retort. But though sand answers this purpose, it has not the effect of iron, which gives the mercury a remarkable degree of brightness and mobility.

Iron calcines most easily and rapidly; and must therefore be a powerful opponent to the calcination or oxydation of the mercury, quickly absorbing any vital air that may be in the apparatus. The greasy matter too, which is in all filings of iron, contributes in the same manner to prevent the oxydation of the mercury. I have very frequently perceived a strong smell of volatile alkali in the vessels in which mercury has been distilled with iron filings. I apprehend that this is formed by the union of atmospherical azote with hydrogen disengaged by the iron from moisture contained in the vessel and materials.

Though this metal does not calcine very perceptibly, when only changed into vapour to be immediately condensed again, it is not incapable of being calcined.

There is a process described in chemical books, by which it is changed into calx or oxyd by the action of air and heat. The heat applied must be such as will keep the mercury constantly circulating; and it must be applied without interruption for several months, to produce a moderate quantity of calx. This is performed in a matrass of a low flat shape, with a long neck, and a capillary opening at the extremity. Some chemists also recommend a small opening below. The mercury is kept continually, though gently boiling; and after a long time, a red calx or oxyd appears on its surface, which continues to increase. It is called *mercurius calcinatus, vel precipitatus, per se*. The combination with vital air in the formation of this precipitate, may be very plainly seen by tying an inflated bladder to the top of the matrass. It will gradually collapse, and in a short time be quite flaccid. Chaptal, a great practical chemist, says that it absorbs nearly eight *per cent*. It is said that a small portion of gold greatly expedites the calcination of the mercury.

The calx is much less volatile than mercury in its metallic form; and even endures the first beginning of ignition, and melts into a beautiful glass. But if the heat be increased above this degree, the calx is gradually converted into vapour, and at the same time returns again to the form of quicksilver; for these vapours, when condensed, afford quicksilver instead of calx. While this reduction of it is performing, a great quantity of very pure vital air is obtained from it, each ounce of oxyd yielding about fifty cubic inches. This method of producing pure vital air was first discovered by Dr. Priestley and Dr. Scheele. But it is to Mr. Lavoisier that we are chiefly indebted for the distinct account of this process, and for the ingenious and most important inferences which may be made from it. I may venture to state this as the most interesting fact in modern chemistry. Mr. Lavoisier saw it in all its importance; and made a multitude of experiments on it, which are models of judicious procedure, and evince the soundest judgment, as well as the greatest ingenuity.

According to him, this calx consists of mercury and oxygen, in the proportion of twenty-eight to one nearly. This oxygen was imbibed from the air in the vessel. It appears from Dr. Priestley's experiments with mercury, agitated in a phial, that the production of the black powder (which is also a less perfect calx) is always accompanied by the absorption of the vital air of the atmosphere. For Dr. Priestley found that the air of the phial was phlogisticated, that is, by what we know now of the matter, the azote was left alone. And when we afterwards agitated the mercury with vital air, he found it not phlogisticated, but consumed or absorbed. Lavoisier observes that this absorption goes on during the tedious process just now described for the calcination of mercury; for the calcination soon stops if the capillary tube be shut up. In this case, if we push the heat a little farther, part of the calx is reduced again. And if we go too far, we burst the vessel. When these facts are compared with the extrication of vital air in the reduction of the *mercurius calcinatus per se*, the inevitable conclusion seems to be, that the union between mercury and oxygen is so slight, that a very low temperature is sufficient for separating them. Mr. Lavoisier varied this experiment in many ways that lead to the same conclusion.

No substance has been so much tortured by the chemists as this metal. It has been united or mixed with almost every substance in nature: and it appears to form some combination with them all; for by simple trituration with any substance whatever, even dry sand, the mercury loses its metallic lustre and its fluidity, and becomes black; at the same time it becomes very sensibly sapid, and affects the nerves of the stomach and the secretory organs. But this is owing to its divisibility, and its disposition to oxydate when presented to the air in such an extended surface.

All the more powerful chemical agents combine with it very readily; and the combination affords a great many remarkable and instructive appearances. I shall first consider its relation to the acids.....

1st, The vitriolic acid has no action in the cold, not even though in its strongest state. If we dilute it with water, it cannot act on mercury, even though assisted by heat.

In order to combine the acid with this metal, we must take the acid in its strongest state, and employ the assistance of heat to make it act. It will then dissolve half or two thirds of its weight.

When the acid becomes near boiling hot, it begins to dissolve the mercury with effervescence. This effervescence is occasioned by the change of a part of the acid into sulphurous acid, which change always happens to a part of this acid, when made to act on metals in its strong state, without addition of water. The dissolving metal, not having water to act upon, and to supply it with oxygen, attracts a part of the oxygen of the acid. This, in consequence, is decomposed, and returns more nearly to the state of sulphur from which it was originally produced. And there are even many examples of the change of a part of this acid into perfect inflammable sulphur, when it is made to act in its strong state on some of the metals. On account of the change which a part of the acid undergoes in this manner, we must use more of it than what actually remains afterwards combined with the oxyd of the mercury. In proportion as the *oxydated metal* and acid unite, they form a saline compound of difficult solubility, which is accumulated around the mercury in form of a white matter. And if we have used a proper quantity of sulphuric acid, the whole is converted into a white saline mass, whose regular crystals are four-sided columns, terminated at each end by pointed pyramids. Seldom, however, does it attain this complete form.

This is a singular salt, and presents an appearance of much importance to be attended to in the metallic salts. It seems to be a mixture of two very different substances. For if boiling water be applied, we separate from this mass a portion having a yellow colour, and almost perfectly insoluble in water, and not containing a particle of sulphuric acid. Its colour occasioned its being called *turpethum minerale*: and it was conceived to be a perfect calx of the mercury, like that obtained by the action of heat and air. It is indeed found to be a perfect oxyd, united only with the oxygen which was separated from that part of the acid which escaped in the form of sulphurous acid, that is, deficient in oxygen. This turbith, when urged by strong heat, is de-

compounded, affording mercury in its metallic form, and vital air.

The other portion, separated by the boiling water, consists of the oxyd now described, combined with the acid; and is a real *sulphat of mercury*. It crystallizes in slender deliquescent needles. Still this sulphat exhibits nearly the same properties with the mass from which it was separated. For long boiling separates the acid from part of it, and leaves it in the form of a turbith. And I believe the same effect will be produced on what has now been separated, and that the whole may in this way be changed into turbith. When the turbith, and water first poured on it for washing it, have boiled together for some time, an effervescence takes place; and some elastic matter escapes, which I have not examined. In these processes, it is plain to observation that the first boiling water separates the greatest part of the acid. But if the mixture be allowed to cool, the calx resumes a considerable portion of it: and the paleness of colour shews that the turbith is not nearly perfect. The water containing the acidulous sulphat should therefore be poured off immediately.

With respect to the other part of the saline mass, which has been cleared of the mercurial oxyd, and is a true sulphat of mercury, I must observe, that it is a very acrid mercurial compound, and speedily destroys all organized substances*. It is much less volatile than quicksilver: and when urged by a strong heat, it sublimes without decomposition. The truth is, that the ingredients differ so little in volatility that they should rise together, and we should not expect any decomposition. But if the vapours come in contact with the atmosphere, they seem to be completely decomposed, and

* The various appearances which this salt exhibits arise from a different proportion of sulphuric acid which it may contain. In its yellow state, it contains least of all; when white, it contains more. Washing the white mass with boiling water makes it yellow, the water taking off the more soluble part. When this is evaporated and ready to crystallize, or would crystallize by cooling, the addition of a very minute quantity of acid prevents the precipitation till farther evaporated,....shewing plainly that the greater solubility arises from an excess of acid. Consult Fourcroy for a very distinct account of all these states.....EDITOR.

this in a variety of ways, yielding mercury, cinnabar, sulphur, and sulphurous acid, according to circumstances.

The sulphat of mercury is decomposed by alkalis. Fixed alkali precipitates the mercury of an orange brown colour, when mild, but more approaching to yellow, when caustic. Volatile alkali, in its caustic state, will scarcely decompose the sulphat: but by the help of a double elective attraction, it decomposes it very readily, when united with excess either to carbonic or muriatic acid. Lime-water also precipitates the mercury, of a brown or yellow colour, according as little or much lime-water has been employed.

I observe that some chemists assert, that by repeated distillation of sulphuric acid from mercury, in this process, the mass becomes more and more fixed, and melts into a blood red fluid before it evaporates. (*See Cornette Mem. Acad. 1799.*) I have not observed this; nor has Mr. Bayen, who has made a great many very judicious and interesting experiments on this subject.

The nitric acid dissolves mercury more quickly and readily than any other acid does. The most convenient strength of the acid is when diluted with about an equal weight of water; in which diluted state it is called aquafortis. It is properly diluted when an ounce of it can dissolve an ounce of mercury.

This solution exhibits no remarkable appearance at first. Generally the metal lies quiet for some little time at the bottom: and all that we observe is a green colour in that part only of the solution, where it is in contact with the mercury. This colour gradually spreads farther up: and small bubbles appear rising from the mercury, but are absorbed as they ascend, till the green colour produced by them at last reaches the surface. They then fly off in the usual form of red fumes. If water be carefully added to the mixture, before the green colour reach the surface, the bubbles will rise a little way in the water before they are absorbed: and they tinge it green, and promote the mixture of the acid liquor with the water above it. By very careful management of the process in this way, Bergmann has sometimes obtained a complete solution, without any escape of red fumes. This, however, is a very rare case: and the solution has rare properties. Had not

the water been added, and had the fumes broken out, and a complete solution been obtained, the addition of so much water to the solution would have caused a great portion of the mercurial nitrate to fall down. But the solution obtained without effervescence will bear any dilution with water.

The more common phenomenon of the process is a speedy formation of the ruddy effervescence. The rise of the bubbles from the mercury is accompanied by a considerable extrication or formation of heat. And when the solution is carefully observed, the bubbles are plainly seen to form in all parts of the green liquor. In short, the acid is changing from nitric to nitrous: and an elastic matter breaks out that is deficient in oxygen. The solution grows very warm: and the fumes become very copious, and blood red. Hence we must conclude, in conformity to the numerous facts already mentioned on different occasions, that the metal is now acting on the acid, and decomposing either the whole, or only a part of it, by abstracting from it a portion of its oxygen.

When those fumes, instead of being allowed to escape into the atmosphere, and mix intimately with it, are made to pass through a narrow glass vessel, the ruddy colour soon disappears in the tube. and the expelled gas becomes quite transparent there, and almost colourless. It may be collected in the same way that we have employed for other gases, by making it pass into inverted jars filled with water, and standing in a cistern of that fluid. Taking this method, we find that all the acid qualities are gone. The gas has scarcely any taste. It has very little attraction for water. Distilled water dissolves about one-eighth of its bulk; but retains it so weakly that a short exposure to the air dissipates it completely.

This colourless, elastic, aerial matter, was first described by Dr. Priestley, who called it *nitrous air*. The French call it *nitrous gas*. The most common name of it in England, however, is still *nitrous air*. It is now well known to be a portion of the acid of nitre, disguised or changed by the loss of a great quantity of its oxygen, which the dissolving quicksilver has abstracted from it. One proof of this is, that if we separate the quicksilver from the acid, either by precipitating it with a pure alkali, or by the action of heat alone,

we obtain, by either way, an oxyd of the mercury, which is not unlike to the oxyd obtained by the action of air and heat. And like that oxyd, it yields a large quantity of pure vital air, when heated red hot in a retort, the mercury at the same time resuming its metallic form. We have another proof, by mixing this elastic fluid with atmospherical air, or vital air, which has much more effect. Either of them, by supplying oxygen, changes the nitrous air into nitrous acid, which shews itself in red vapours, and is immediately attracted and absorbed by the water. Much less of the vital than of the atmospherical air is sufficient to produce this change on the nitrous air: and it is evident, from other experiments, that the atmospherical air produces its effect only by virtue of the vital air which it contains.

When these red vapours are formed, a considerable heat is produced in the glass. This heat is supposed by the French chemists to be a part of the heat, or matter of heat, or calorique, which was contained in a latent state in the composition of the two elastic fluids. (*See note 56. at the end of the Volume.*)

By means of this nitrous air, Dr. Priestley very ingeniously contrived to distinguish wholesome or respirable air from the different kinds of tainted or noxious air; and endeavoured to measure the *different degrees of wholesomeness* or purity in common atmospheric air. His method of doing this is described in the volumes he has published; and his apparatus was such as enabled him to subject a small quantity of air to this sort of trial or test, as he calls it. The principle of the method is briefly this. Nitrous air is the vapour of nitric acid, deprived of part of its oxygen. If, therefore, a cubic inch of it be mixed with as much vital air as will make up the deficiency, they will unite and form nitric or nitrous acid, miscible with water. If, therefore, a cubic inch of this gas be thrown up into a jar inverted over water, and containing an air consisting of as much vital air as is required by this nitrous air, and three cubic inches of any other gas immiscible with water, whatever may be the bulk of this compound air, it will be reduced to the bulk of three inches. If, therefore, nitrous air be very uniform in its composition, a single experiment will inform us what bulk of

vital air it will unite, and disappear with, by absorption in the water. Therefore, throwing up nitrous air, till there ceases to be a diminution, will inform us how much vital air is in the mixture. Nay, as this requires time, and certain complicated precautions, a series of proper experiments will teach us the proportion of vital air, by means of the contraction occasioned by mixing a given measure of nitrous air with any quantity of compound air: and we may proceed on this principle, that 100 parts of nitrous air absorb 48 of pure vital air, so that both disappear.

Dr. Priestley's apparatus consists of a tube, in which the bulk of the mixed airs is measured. It is about three feet long, and one-third of an inch wide. In examining atmospheric air, or air like it, he mixes two ounce measures of such air with one of nitrous air in a small jar; and soon after throws up the mixture into the long tube, the cavity of which is divided into ounce measures, and each of these into a hundred parts by a scale: and he expresses the result of the trial, by telling the number of these parts which the mixture fills after the absorption is over. The best air, therefore, gives the smallest number.

In trying air better than atmospheric, he adds to one measure of such air two measures of nitrous air, which quantity of the nitrous air is enough for the purest vital air.

Other authors have endeavoured to make improvements in the manner of employing nitrous air for this purpose. The Abbe Fontana has studied this point with particular care; and has described his *apparatus*, or the *eudiometer*, as it was first called by Landriani, in which there are many neat contrivances. Mr. Cavendish also has given some accurate and skilful remarks in the 73d volume of the Philosophical Transactions. And Dr. Ingenhousz has made some improvements in the manner of using the apparatus. But the contrivance which appears to me the most simple and convenient, as well as the most exact, is that of Mr. Sausure.

He uses a phial, which he calls the *receiver*, containing about five and a half ounces of water. Its diameter and height are nearly equal: and it has a ground stopper well

fitted. He has another small phial, called the *measure*, which contains somewhat less than one-third of the former. He has also a small funnel, and a small exact balance. (*Saussure Voyage dans les Alpes*, p. 514.)

Having prepared the requisite quantity of nitrous air on the spot, he proceeds as follows: 1st, Having filled the recipient with water, and holding it under water in the bucket, he introduces into it two measures of atmospheric air, and one measure of nitrous air. He then shuts the recipient with its stopper, and shakes it under water, opening it now and then, to let in the water. This shaking and opening is performed just three times in every experiment, in order that all may be perfectly similar. 2d, The recipient is now stopped close, and its outside is wiped quite dry. It is then weighed, and its weight compared with what it would be if three measures of common air had been admitted. The difference in his apparatus amounted commonly to one ounce six drachms and forty grains. N. B. His measure contained one ounce six drachms twelve grains of water. Supposing, therefore, that two parts of nitrous air combine with, or are decomposed by one of oxygenous gas, the quantity of this gas in common air is, by the above result, just one-fifth of the whole common air, or 340 in 1704: more exactly, it is 22 *per cent*. By such experiments he learned that the air of the valleys among the Alps, and at Geneva, is better than that on the tops of high mountains by about nine grain measures of oxygenous gas in the above two measures. This is probably owing to the action of plants during sun-shine.

I am persuaded that this apparatus is more useful than the expensive and fragile eudiometers consisting of tubes and stop-cocks. But when I reflect on the unavoidable differences in the proportions of the ingredients of nitrous air extemporaneously prepared, and on the different propensities of ordinary water to absorb or emit elastic fluids, I cannot think that these eudiometrical experiments are a proper foundation for any accurate judgment of the salubrity or unwholesomeness of airs. And I should be sorry to see much dependance placed on them. I have always considered them as too delicate for the hand of any person but a judicious

chemist, perfectly at leisure. The odds of 10 or 20 grains in 1740, is an error from which it would be difficult to secure ourselves. Yet even this is a very great part of the greatest differences that have been observed. It is also very inaccurate to consider this experiment as a test of the wholesomeness of air, and to call the instrument a eudiometer. Chemically speaking, it only measures the quantity of oxygenous gas contained in every air. We know very well, that the commixture of some exhalations, particularly of flowers of the lily kind, in a quantity too small to be perceived by such a test, gives the air a power of affecting some of our organs in a way, which, though not immediately deadly, is yet extremely prejudicial to good health.

Accordingly, the experiments made to examine the goodness of air by employing nitrous air, do not always agree exactly together, even though made with the same airs and materials, and the same apparatus. And when we wish to be exact, it is necessary to repeat them several times, and to take a medium of the results. And when we choose to compare two portions or specimens of atmospheric air with one another, the experiments for this purpose should always be made at the same time, and in the same place, and with the same nitrous air recently prepared; experience having shewn that nitrous air is sensibly different in its quality, as it is prepared at different times, and in different places. This is now understood to proceed from the more or less violent change which the acid suffers when we are preparing the nitrous air. A part of the acid always undergoes the changes you have seen: but a small portion of it is completely decomposed, the whole oxygen being taken from it: and then what remains of this portion is azotic gas, which cannot be brought back to the state of nitric acid by simple mixture with respirable or vital air. There is only one way by which we can bring it back to the state of nitric acid, or convert it into that acid; that is, by mixing three measures of it with seven measures of vital air, and then promoting the union of the two airs, or their action on one another, by a strong heat, or by repeated flashes of electrical fire, in the manner practised by Mr. Cavendish, in the course of those curious and important experiments which I have frequently referred to, as the great

support of the new chemical doctrines and discoveries. Now, when metals are dissolved in nitric acid, some small portion of the acid is, as I said just now, so totally deprived of oxygen, that it is changed into azotic gas: and this happens more or less according to the violence, rapidity, and heat, with which the dissolution is performed; and therefore the nitrous air which we obtain, turns out different on different occasions, by its containing different quantities of azotic gas, and being more or less fit for the examination of the wholesomeness of respirable air.

By this trial air is judged to be wholesome, or fit for respiration, in proportion to the quantity of nitrous air which it can decompose: and this is known by the diminution of bulk which happens in the mixture of the two airs as confined by water. If there be no diminution of the two airs, the one which was mixed with the nitrous air is totally unfit for the support of animal life, even for a moment; and if there be but little diminution, an animal will die in it in a very short time.

When common respirable air is examined in this manner, by mixing it with an equal measure of nitrous air, the diminution of the mixture, when shaken with water, has been observed to be 90 or 100, or 110, or even 120 parts in 200 of the mixture,* with frequent variation however of the result, though the trial be made with the very same materials, and in the same place.

For all these reasons, I think, that it may be worth while to try whether Dr. Scheele's way of examining the goodness of atmospherical air, or the quantity of vital air it contains at different times, and in different places, may or may not be preferable to this. Scheele's way was, as you may remember, by absorbing the vital part by humid sulphuret of iron filings.

To finish these remarks on the changes which a portion of the nitric acid undergoes while it dissolves the metals, we may notice here, that part of it, on some occasions, is reduced to an intermediate state, between the state of nitrous air and that of

* In some of Dolomieu's experiments, the loss was from 118 to 85; but the heat of the air was very different when so great a difference was observed. In the first case, the wind was north-west, and the thermometer $55\frac{1}{2}$. In the second it was a sirocco, or south-east wind, and the thermometer 82.

pure or perfect azotic gas. In this intermediate state, it is a colourless elastic fluid or gas, like nitrous air; but has different properties.

1^{mo}, It is much more absorbable by water, and can be separated again from the water by heat, unchanged.

2^{do}, It is not converted into nitrous acid by the admixture of vital, or of atmospherical, or of nitrous air; or, to express it more accurately, it does not unite with the oxygenous gas in these airs by simple mixture.

3^{tio}, Though it is totally unfit for supporting animal life by respiration, it brightens and enlarges the flame of a candle immersed in it. And inflammable air mixed with it and fired, explodes much in the same manner as when it is mixed and fired with atmospherical air, but with a green flame. But it has very little power to maintain the combustion of charcoal, or of some other combustible substances.

4^{to}, It may be produced or obtained from nitrous air, by exposing such nitrous air to the action of substances or mixtures which have a strong attraction for oxygen, such as the sulphuret of potash, the humid sulphuret of iron, the muriat of tin, &c. From several phenomena which have occurred to me in experiments, I apprehend that the most expeditious way of obtaining it pure, would be to employ the neutral salts formed by the alkalis and the sulphurous acid. I imagine that it is by such intermediate that even the sulphurets effect its production. Such matters first change the nitrous air into this intermediate kind, in two or three days; and afterwards, by a continuance of their action, change it completely into azotic gas, the bulk of it being at the same time very greatly diminished. (*See Note 57. at the end of the Volume.*)

It may be also produced, and in a purer state, by some particular modes of managing the action of nitric acid upon the metals, which we shall notice soon.

It was first discovered by Dr. Priestley, who gave it the name of *dephlogisticated nitrous air*, on account of its promoting the burning of a candle and having the power to brighten and enlarge the flame of it. He discovered several different ways of producing it, and made many experiments with it. But its nature has been best illustrated and explained by the society of

philosophical chemists at Amsterdam, in consequence of an ingenious inquiry, and a great number of experiments they made with this view. (See a very good account of these experiments in the *Analytical Review*, vol. 17. p. 356.)

They are of opinion, that, like nitrous air, or nitrous gas, it is a compound of azote and oxygen, combined by chemical attraction: but that it contains less oxygen than nitrous air does, though a greater quantity than that contained in atmospherical air. But in the air of the atmosphere, the oxygen is closely combined with the latent heat only, or is in the form of a gas, simply mixed with azotic gas; whereas, in the sort of air which we are at present describing, the oxygen is combined, as I said just now, with the azote, by chemical attraction.

The chief reason for thinking the union of azote and oxygen different in these two compounds is, that the peculiar qualities of this last take place at a pretty precise proportion of the ingredients, somewhat like other chemical combinations, when a mutual saturation takes place. I cannot say that this is a very strong argument, although it is not without some weight. But it is more difficult to account for its increasing the flame of a burning body, while nitrous air, which contains more oxygen similarly combined, so far from having such effect, extinguishes flame in an instant.

The proportions of oxygen in these different gases, or airs, are thus stated by these gentlemen, from some accurate experiments:

1mo, The atmospherical air is known to contain 27 or 28 parts of oxygen gas, or vital air, in 100 parts of the air.

2do, The air or gas we are now describing, contains 37 or 38 parts of oxygen in the 100.

3tio, And nitrous air contains 68 parts.

These gentlemen have given a new name to the gas we have just now described. They name it *gaseous oxyd of azote*. But this name is just as proper for nitrous gas, which is, like the other, *azote, in the state of an oxyd*, or combined with oxygen, but with less of it than what is necessary to form an acid. It would have been better, therefore, to have named the gas we

have been considering, the less oxydated nitrous gas, or, the less oxydated oxyd of azote*.

They have also made an ingenious attempt to explain its peculiar properties, especially the power it has to promote the burning of a candle, and to brighten and enlarge its flame, although breathing animals cannot live in it a moment. These apparently inconsistent qualities they impute to the peculiar mode of combination of the elements of this gas, which are so strongly united, that the oxygen, though it has power to act on hydrogen with the assistance of heat, has very little power to act on carbon; and accordingly, the gas has very little power to promote or sustain the inflammation of charcoal. But in the respiration of animals, it is necessary that a carbonaceous principle be discharged from the blood, which carbonaceous principle is dissolved and carried away from the lungs, by respirable air in the form of carbonic acid gas; whereas the gas we have now described cannot serve this purpose. But it can serve for sustaining the flame of a candle, for this reason, that tallow, and all other oils, contain a much larger proportion of the hydrogenous principle than of any other in their composition. And the oxygen of this gas is in that state which disposes it to unite readily with hydrogen, while the hydrogen is separating itself from other matter, and before it has time to attract latent heat, and to expand with it into a gas. This state of hydrogen was named by Dr. Priestley the nascent state of inflammable air. We have already had several examples of a greater facility of union in this particular condition of things†.

The quicksilver, while it produces these changes in a portion of the acid, is itself changed into an oxyd, by its union with the oxygen which it has attracted; and this oxyd of the quick-

* Surely the name *nitrous oxyd*, given it by Chaptal and others, is more agreeable to the general plan of the French nomenclature. This compound seems to be in the smallest possible degree of oxydation....EDITOR.

† Perhaps this explanation may not be thought to agree very well with the proportion of oxygen that appears, by the experiments of Lavoisier, La Place, and Monge, to be required for the inflammation of equal weights of hydrogenous gas and charcoal; the last requiring so much less than the former. Nor does it agree with the superiority that is assigned to carbon, in affinity for oxygen....EDITOR.

silver is then combined with the remaining acid, or is absorbed by it*.

The compound, or mercurial nitrate, being sufficiently soluble, part of it will, in a day or two, crystallize at the bottom of the solution. The rest continues dissolved by the water of the acid, and forms a heavy, transparent, and nearly colourless fluid, very acrid and corrosive with respect to animal and vegetable substances. A drop of it makes an indelible black mark on the skin. The salt which it contains is sometimes more, sometimes less soluble in water, according to the quantity of acid with which the metal is combined, and in proportion as it is new, or has been long kept; for the same thing happens to it in some degree as to the solutions of iron. The metal which, while it is dissolved, is evidently oxydated to a certain degree, by decomposing a part of the acid, becomes somewhat more oxydated afterwards in the solution: it therefore becomes less soluble, or requires a greater quantity of acid to keep it dissolved; and with that acid it forms a compound not quite so soluble in water as the similar compounds which contain the mercury in a less oxydated state.

I may farther observe, that the solubility of the nitrate of mercury varies exceedingly with the temperature of the water. Water boiling hot takes up a great deal more, which is deposited on cooling, in crystals. Nay, for the same reason, the acid will dissolve more of the mercury, by the assistance of heat, and this is speedily let go in cooling, and is of a different kind, as we have seen already, from what is obtained from the metal when it is dissolved in a cold temperature, being more oxydated. Also, if we add a great quantity of distilled water to a strong fluid solution, we have a precipitation of an oxyd, yellowish, if hot, and white, if cold. A small redundancy of

* This experiment, the solution of quicksilver in the nitrous acid, is, perhaps, the most perspicuous and instructive example of the general nature of metalline salts; and for this reason has met with particular attention from Mr. Lavoisier and his coadjutors. The character of the compounds, in their different states of oxygenation, are more distinct than in any other example. There seems to be several degrees of this: and each has a uniform effect, even on the structure of the crystals. They are also very distinguishable, by the differences in their affinity for water, being so singularly and uniformly affected by its being hot or coldEDITOR.

acid prevents this precipitation; so various are the appearances of this *Proteus metallorum*. But these differences are similar, as I have said, to what we see in iron: and they are produced in the same way, or by the same causes, only more diversified.

The nitrate salt of mercury has attracted much notice. It was tortured by the alchemists into a thousand forms, being the produce of their favourite mercury, on which they professed to build their greatest hopes, and of the wonderful acid, which manifested the most remarkable and important properties. This precipitate is white or yellow in its first preparation, in the circumstances I have considered. But, if long continued in a low heat, it becomes of a full red, perfectly similar in appearance, and also similar in many of its properties, to the *mercurius precipitatus per se*. It is called RED PRECIPITATE.

This compound is much used in medicine and surgery, as an escharotic, or cautery, for destroying fungous flesh, &c. It has also become of great value to the philosophical chemist, as affording the readiest method for obtaining oxygenous gas in its purest state. It is, therefore, of importance to prepare it in the most perfect manner, and particularly, to prepare it so as to be uniform in the proportion of oxygen it contains.

When the mercurial-nitrate is simply evaporated to dryness, especially when the precipitation has been partly effected by cold water, it is white, or yellowish; for which reason it has been called NITROUS TURBITH. If it be exposed to a very low red heat in this state, a considerable portion of acid is driven from it, and becomes of the fine full red colour, fit for the market. When this is done in a sand bath, it frequently happens that before the central parts and surface have acquired the proper colour, the part at the bottom has been deprived of its oxygen, and the mercury revived. Dr. Higgins, therefore, performs this process in a deep porcelain dish, under a muffle, applying the heat all around, and covering the dish with a glass plate. A small portion of mercurial muriat usually exhales in this process. It arises from impurity in almost all the nitric acid that we can procure: even a little of the nitrate itself sometimes goes off. Chaptal, to have it in perfection, with a rich colour, pours fresh nitric acid on it, and distils it to dryness, three times.

. I said that, in the state of a nitrate, this compound exhibited certain uniform differences in the form and structure of its crystals. If the solution has been made without the assistance of heat, and the mixture kept close during the process, and if it be allowed to evaporate spontaneously, the crystals are thin square plates, whose four sides are formed into an edge, like that of a stone-cutter's chizel, and having the four angles cut off; that is, the crystals are formed of two tetrahedral pyramids, joined at their base, and having the angles cut off. (*See Romé de l'Isle*, No. 38. VI. 11.)

But if the evaporation has been promoted by considerable heat, the crystals are flat-pointed spiculæ, having the flat side elegantly striated in an oblique direction, like a sword blade which has been ground by holding it very obliquely on a rough stone. If the solution has been effected by heat, the crystals are also flat spiculæ, like lancets: but the striæ are now parallel to their lengths. This pointed form of all the crystals has been much insisted on by the mechanical chemists, in their attempts to account for the corroding powers of the mercurial nitrate, but, unluckily, the most corrosive are the crystals in flat plates.

Mr. Fourcroy has treated this subject with the same distinctness and perspicuity as the solution in sulphuric acid. And his analysis of the different states of the nitrate seems to me very judicious and instructive.

The muriatic acid, in its ordinary state, has little power to act on mercury in its metallic form. This is a consequence of the weak power, or rather *want of power*, in this acid to oxydate the metals: and they must be oxydated in some degree, in order to form compounds with acids. But the muriatic acid, oxygenated by manganese, readily unites with metals in general, and forms a saline compound, the oxygen being in this case supplied to the metal by the acid. We can therefore easily obtain a compound of mercury and the muriatic acid, by employing this acid in its oxygenated state. Or, if the quicksilver be first oxydated by air and heat, or by other acids than the muriatic, that acid will then readily unite with it, and even separate the other acids from it.

Whether it has in this manner separated the mercury from another acid, or dissolved the mercury calcined by the action of heat and air, no difference can be perceived in the muriat. If, for example, *mercurius calcinatus*, and red precipitate (accurately prepared) be dissolved in separate quantities of muriatic acid, no difference whatever can be perceived. This must be received as an abundant proof, that red precipitate contains no nitric acid, or any thing that it may not acquire by simple exposition to heat and air.

The compound of the muriatic acid and mercury is soluble in water; but not so easily soluble as the compound with the nitric acid.

The usual method, therefore, for combining quicksilver with the muriatic acid, is, first to oxydate or dissolve the metal with another acid, the nitric for example, and then apply to it the muriatic, which can be applied effectually by several different ways. We can apply it pure, or combined with an alkali, as in common salt.

When applied pure to the mercurial nitrate in solution, a copious precipitate, or rather coagulum, is immediately formed. This is usually called the white precipitate of mercury. If we apply common salt, or any earthy muriat, we have similar precipitate of mercury, and a neutral or earthy salt in solution.

If, however, we use the oxygenated muriatic acid, we do not obtain the same precipitate; because the mercurial muriat in this case is very soluble in water; whereas the common muriat is far less so, indeed scarcely soluble, requiring almost 2000 times its weight of water, according to Beaumé and Lemery. The muriat, and the oxymuriat (as the French call it) of mercury, differ also in many other important properties.

But when the muriat of mercury is formed by these methods, the separation of it afterwards from the other acids, or salts, which are in the mixture, is very difficult. These methods, therefore, are not convenient for practice: and a different one is commonly followed, by which this muriat is formed, and at the same time separated by sublimation from the other materials employed in the process; this muriat being totally volatile in a moderate heat.

The proper materials for this purpose are,

1st, The quicksilver, reduced either to an oxyd, or to a saline compound, by the action of the nitric or sulphuric acid.

2dly, Materials which, when heated, will supply to the quicksilver a proper quantity of muriatic acid in the form of dry vapour. You will find in Newman's Chemistry a copious list of all these mixtures for procuring a combination of mercury with the muriatic acid.

The process which was formerly most generally recommended in chemical books, was to mix a dry nitrate of mercury in powder, with an equal quantity of common salt, and as much exsiccated sulphat of iron, and to sublime this mixture. This is a sure process for obtaining a perfect corrosive muriat of mercury.

Neuman says, and I believe he says truly, that those processes in which the nitrous acid has acted, produce a more complete union of mercury with the acid. The mercury is more completely oxydated by this previous treatment; and will therefore unite with a greater quantity of the acid, and make a more active or corrosive compound. The truth is, that the metal attaches to itself a greater quantity of unmixed oxygen than it can obtain in any other way, and it is on the abundance of oxygen that the corrosive nature of the muriat entirely depends. But the process now practised is more simple.

The quicksilver is first combined with the sulphuric acid, and the sulphat mixed with dry common salt in fine powder: and this mixture is sublimed. This is Neuman's seventh process. The sulphuric acid quits the quicksilver to join itself to the alkali of the common salt, forming with it Glauber's salt, or sulphat of soda; while at the same time, the muriatic acid unites with the oxyd of quicksilver, and they sublime together in the form of a corrosive muriat of quicksilver. The sulphat of soda not being volatile, remains at the bottom of the subliming vessel.

This compound, when well made, dissolves totally in water; but requires about nineteen times its weight of water.

When it is less soluble than usual, we find that it will effervesce with nitric acid, being in a state which resembles in

some degree another preparation, to be mentioned presently, in which the mercury is redundant, corroded, but not perfectly oxydated: and therefore it decomposes the nitric acid. It dissolves more easily, if some muriatic acid be added, or sal ammoniac, or common salt; the muriatic acid in these salts acting in some degree, in consequence of the force with which it attracts the quicksilver. It is extraordinary that two volatile substances, often sublime together, should become more fixed. Yet this happens with mercurial sublimate, and sal ammoniac.

It must be considered as a triple salt. It is an ancient preparation, and was called *sal alembroth*, *i. e.* salt of the wise, or of the artists, by the alchemists. It crystallizes readily, by cooling the solution made in hot water.

This preparation was called the *corrosive sublimate of mercury*, both on account of its being in fact very acrid and corrosive, in consequence of the quantity of muriatic acid it contains, and also to distinguish it from another sublimate of mercury which resembles it a little in external appearance, but is quite free from any corrosive quality. It is now called the *hydrargyrus muriatus*. This *mild sublimate*,....*mercurius sublimatus dulcis*, or *calomelas*, or *hydrargyrus muriatus*, as it is now called, is produced by a process which was contrived at random, in order to correct the corrosiveness of the former preparation.

Corrosive sublimate is carefully mixed, by trituration, with an equal quantity of mercury, or with as much as can be ground with it, so as completely to disappear: and this mixture is then sublimed. It rises very imperfectly sublimed in the first sublimation, and therefore of a dirty colour. Repeating the whole process makes it whiter, and by a third sublimation, we have it in its best state,....a white striated mass. The process is exceedingly hazardous to the workman who mixes the materials; for the dry powder is apt to be received into the lungs; and a very small quantity may be fatal. This is remedied in a great measure by adding a little water.

The compound is a *corroded mercury*, quite insoluble and insipid, having no more taste than the mildest preparations.

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In the mercury is much less oxydated than in corrosive sublimate.

I called this a random process; because at the time of the first preparation of this drug, the chemists had no knowledge of any properties of mercury which could lead them to expect an intimate combination. Nay, to this hour it is not easy to say what is the exact nature of it. The mercury is here not merely oxydated, but combined with the acid, in a state intermediate between that of an oxyd and a muriat. Beaumé, a very judicious and experienced pharmaceutist, affirms, that by reason of the great difference in the volatility of corrosive sublimate and sweet mercury, the two cannot be uniformly mixed by any number of sublimations; and recommends, as the only way of freeing the drug from corrosive quality, to boil it with water, and a little sal ammoniac, by which all the corrosive part is dissolved.

This compound is not very different from what may be obtained by dissolving mercury in the nitric acid; for it may be saturated with metallic mercury without allowing the formation of nitrous gas: and then pouring muriatic acid on the solution, a salt immediately falls down, scarcely distinguishable from mercurius dulcis.

The extremely corrosive nature of the mercurius sublimatus is very evidently owing to the action on the inflammable matter in the substances corroded by it. Mr. Berthollet, while he held the Stahlian doctrine, attributed the corrosive quality of all metallic salts to their action on the phlogiston; His chief arguments were drawn from his experiments with this compound. When digested with vinous spirits, a considerable portion became sweet mercury, and some was revived. When distilled along with oils, the mercury sublimed in a metalline form, and the oil was rapidly destroyed, and left a prodigious quantity of charcoal. He now explains the same phenomenon by the powerful action of the oxygen. No doubt there is a rapid combination of oxygen with the inflammable matters. But we do not see how the combination of it with the metal tends to promote its combination with other substances: and I am by no means certain that the corrosive salts are more so than the acids themselves. It were, perhaps, as just to say, that the natural corrosiveness of the acids is

less mitigated by a combination with metals than with alkaline substances. Nor is Mr. Berthollet's opinion consistent with the inoffensive, nay sanative quality of the martial and saturnine compounds.

It is found that there is no intermediate state of oxydation between this of corrosive sublimate and that of mercurius dulcis. When too little mercury has been triturated with the corrosive sublimate, the mild sublimate is still formed perfectly mild: but, under it, next to the vessel, we find the undecomposed corrosive sublimate.

Thus we have seen how mercury may be combined with each of the three fossil acids, and with some in different proportions, and in different states.

Mr. Margraaf discovered that it may also be combined with the vegetable acids and with the fixed alkalis. And others since, by following his method, have found that it can be joined with a number of other acids.

Mr. Margraaf's method is to precipitate the mercury from a nitrate of mercury, by a pure fixed alkali. The precipitate dissolves with effervescence in acetous acid, in vinegar, in the acid of lemons and of sorrel, and even in Rhenish wine. It requires digestion, but has no difficulty, and a great deal is dissolved. See also *Fourcroy*, IV. 277. also the publication of the Dijon academy. The acetate of mercury is the basis of Keyser's pill.

With respect to the order in which the acids attract mercury, I shall only observe, that of the fossil acids, the sulphuric and the muriatic attract the metalline oxyd more strongly than the nitric, as appears by the process of the corrosive sublimate. The sulphuric acid finding the mercury properly oxydated, unites with it very readily, without the assistance of heat. These two acids can also be combined with the mercury, by double elective attraction, or double exchange, when neutral salts which contain them are added to the solution of mercury in nitric acid, *e. g.* vitriolated tartar, or Glauber's salt, or vitriolic ammoniac;...and in the same manner, any of the compound salts which contain the muriatic acid.

Mr. Chaptal gives another process extremely simple; and recommends it as producing a very perfect mercurius dulcis.

Decompose mercurial water (solution of nitrate of mercury) by a solution of common salt. This throws down a white precipitate, which gives by sublimation a mercurius dulcis. Scheele practised the same process.

And by a similar double exchange, this metal may be easily combined with the acid of tartar, or with that of salt of sorrel, with which acids it forms a pearly precipitate, that is probably the preparation of mercury used in China.

It can also be combined in the same manner with the acid of phosphorus.

Let us next consider how it may be separated again from the fossil acids.... I said already, that neither the sulphat nor the muriat of quicksilver can be decomposed by heat;.... the acid and metal in these compounds rise in vapour together.

It is not so with the nitrat. The quicksilver remains in the form of a red oxyd, which if the acid be expelled from it as completely as possible, by the continued action of heat, becomes very similar to the calx or oxyd of quicksilver prepared by the action of air and heat. By the deep colour of the vapours of the nitrous acid thus expelled from the quicksilver, as well as the appearances during its dissolution, it is evident that the metal retains a great quantity of the oxygen of the acid. This oxyd is much less volatile than mercury: but if made red hot, it is totally converted into vapours or elastic fluids.

In collecting these vapours, we obtain by a proper apparatus,

1^{mo}, A quantity of nitrous acid in red fumes, but too small to be condensed.

2^{do}, A small portion of the quicksilver, which is combined with a part of the acid vapour, and forms with it a yellow sublimate in very small quantity.

3^{tio}, The greater part of the quicksilver gradually distils over, restored completely to its fluid metallic form,....and

4^{to}, Along with this a large quantity of vital air is obtained. This vital air is much purer than that which is obtained from nitre. Still, however, it is not perfectly pure. It is always tainted with a minute quantity of azote; and, I

believe, with a small portion of the nitrous acid, and even of the quicksilver itself.

This manner of preparing vital air was first discovered by Dr. Priestley.

He obtained it from *mercurius calcinatus*, by means of a burning glass, on the 1st of August 1774: and soon after, from red lead moistened with nitrous acid, by distillation in close vessels. Next month he went to Paris; and communicated his discovery of this wonderful fluid to Mr. Lavoisier, and other members of the Academy of Sciences, then assembled at his house, who were surprised and delighted with the discovery. Returning to Britain, he engaged in so many researches that this had but a share of his thoughts. Mr. Lavoisier, with perhaps as much curiosity, had more of a philosophical and scientific mind, and was a much better reasoner than Dr. Priestley. He took a juster view of this experiment; and saw at once its vast importance in philosophical chemistry; and he repeated Dr. Priestley's experiment with an attention and exactness in all his measures, that was altogether his own. He was the first who made it certain that mercury and other metals have the power to decompose the acid of nitre; and that we are thus enabled to obtain from it two different substances in their separate state, namely *nitrous air* and *vital air*. We obtain by itself nitrous air or nitrous gas, while the mercury is dissolving. And we obtain the vital air afterwards, when we expose the dissolved or corroded mercury to a strong heat. And if we mix these two elastic fluids together, they immediately unite, or their fundamental matters or bases unite, and form again nitrous acid.

It is plain that I here speak of pure azote and pure oxygen. But it is very difficult to obtain these in a gaseous form, and at the same time perfectly pure. The processes for obtaining them always leave a taint of the substances from which they are obtained. It is not difficult to procure the azote very pure. Lime will free it from carbonic acid: and hepar sulphuris will free it from oxygen. It is more difficult to procure vital air perfectly pure, and, especially, free from azote. The red nitrate of mercury affords the best process I know for it. But I have generally found it

tainted with nitrous air, and with azote. I call your attention to this circumstance; because many of Dr. Priestley's experiments, by which he conceived that the theory of Stahl was supported, had results which were certainly owing to such impurities. I have particularly in my eye at present those which he published in 1792.

Thus, therefore, we can by heat alone recover mercury, which has been combined with the nitric acid.

We cannot in the same manner separate the other two fossil acids from mercury alone. I observed already, that they adhered to it too strongly; but we can separate them by other substances which have a stronger attraction for them than mercury has, and some of these bodies still more readily separate the nitric acid.

The substances, which may be thus employed to attract these acids more or less perfectly from the quicksilver, are very numerous.

1st, Water applied in large quantity, and especially if heated, will in some cases produce a partial separation. This is remarkable with respect to the sulphat of quicksilver.

In washing the *mercurius vitriolatus* to make turbith, it is plain that the first boiling water takes from the mercurial calx the greater part of the acid. If, indeed the mixture be allowed to cool, the calx resumes a great part of the acid again, and becomes soluble. I have examined again and again the quantity of acid it contains in these different states with care; and the differences are very sensible. It is difficult to say whether the heat increases or diminishes chemical action in this experiment. It is owing, in all probability, to the different proportions that are necessary, in different temperatures, for saturation, when we mix the compound of oxyd and acid with the compound of water and acid. If this proportion vary very much with respect to the last of these compounds, and very little with respect to the first, the phenomena will be what we observe. The nitrate is not so liable to be decomposed by water: but if largely diluted, it suffers also a little decomposition. The muriat cannot be decomposed by pure water alone.

2do, The precipitates by the fixed alkalis are of a reddish brown colour, approaching thereby to that of a pure oxyd of mercury. The reason is, that they are nearly pure oxyds, but not perfectly pure. They retain a small portion of the acid. The fixed alkali has taken from them nearly the whole, but left a minute quantity, which adheres strongly to the oxyd.

But the precipitates by the volatile alkali are remarkably different from these, and from one another; the nitrate giving a grey, and the muriat a white precipitate. The cause of this difference is, that the volatile alkali has much more power to separate nitric acid from quicksilver, than to separate muriatic acid from it. The volatile alkali has a stronger attraction for the nitric acid than for the muriatic acid: and, in addition to this, the mercurial oxyd does not retain nitric acid so strongly, by far, as it retains the muriatic acid. In the white, or muriatic precipitate, therefore, the mercury retains a considerable part of the acid, but not enough to render it soluble in water. In the dark-grey precipitate from the nitric acid, not only the acid is almost totally separated, but a great part of the oxygen and the quicksilver is restored, in part, to its metallic state, by the superfluous volatile alkali employed in forming the precipitation. The volatile alkali contains hydrogen to attract the oxygen. There is, however, combined with the mercury, a very small remainder of the acid, and some of the volatile alkali. And it also retains a small portion of the oxygen.

There arose great varieties and uncertainties on the separation of mercury from corrosive sublimate, by means of volatile alkali, depending much on the management. The reason is, that the acid seems to attract the mercurial oxyd more powerfully than it does the volatile alkali: for if mercury be dissolved with sal ammoniac, we instantly disengage the alkali in a caustic state. When this alkali is applied to corrosive sublimate, it takes up such acid only as is not necessary for saturating the mercury; and with this forms sal ammoniac, leaving the rest in the form of *mercurius dulcis*. Lemery observed this, by collecting and subliming the precipitate.

3^{to}, Quicklime, too, has power to attract the acid from quicksilver, and to precipitate it even from those acids with which it is most strongly combined. The change of colour, when much lime-water is added, seems to proceed from some action of the lime on the mercury which has not been examined. Half a drachm of corrosive sublimate, thrown into a pound of lime-water, forms a yellow precipitate. This water is used, before subsidence, for cleaning the skin from pimples, tetters, &c. by the name of *AQUA PHAGEDENICA*.

Mr. Bayen discovered that the precipitate of mercury from the acids by means of alkalis, particularly the mild volatile alkali, or by lime-water, when ground with a small portion of sulphur, forms an exploding compound, similar to *pulvis fulminans*. If exposed to heat, slowly increased, till it melt, it explodes with great violence, leaving a residue, which sublimation shews to contain mercury and sulphur, by forming a good cinnabar. Something approaching to this had been observed by Brugnatelli, and others, and also very remarkable detonations by concussion. (*See Note 58. at the end of the Volume.*)

4^{to}, Precipitation of mercury with milk may be mentioned here. A saturated solution of mercury with nitric acid, mixed with hot milk, gives a rose-coloured precipitate of mercury: but when the milk is but just warm, it is of a purple colour. The intenseness of the colour, and the firmness of the coagulum, depended on the heat of the milk. They are soluble in all the acids, and are mild tasted. Other metallic solutions form a coloured coagulum with milk, in the same manner.

Many of the other metals have a stronger attraction for acids than mercury: but these, in general, precipitate it in its metallic form.

If a piece of clean copper be moistened with the nitrate of mercury in solution, and, after remaining a few minutes, be dipped in water, the surface will be found whitened: and if it be then rubbed hard with a clean and soft linen cloth, it will be as bright and white as silver. Putting this in a low heat, approaching to incandescence, the whitening film eva-

porates, leaving the surface corroded by the nitrous acid. Had the copper been allowed to remain long enough in the solution, it would have been dissolved entirely; and running mercury would have been found at the bottom of the vessel. (*See Note 59. at the end of the Volume.*)

Such is the variety of appearances this metal can be made to assume by the action of salts,...red, yellow, white, black powders, white transparent soluble salts. In some of these states it is much more fixed than before.

But however it is thus changed, it can be easily restored again to its natural form. It returns readily to its usual form, when exposed to heat, along with substances which can attract the acid from it, provided they separate the whole acid, or nearly the whole, and reduce the mercury to the state of a pure oxyd. This oxyd, as I observed before, when heated to a certain degree in close vessels, recovers its metallic state. The substances added are iron filings, or fixed alkali, or quicklime, &c. The restoration of the mercury is not called reduction,...but REVIVAL: and the mercury is said to be REVIVED. This refers to its name ARGENTUM VIVUM.

When an oxyd of quicksilver is revived by the simple action of heat, and without any addition, it often happens that besides the vital air, which it affords in great quantity, there is mixed with this a small quantity of carbonic acid. This is supposed to have been attracted from the atmosphere when the oxyd was too much exposed to it.

Neither mercury nor its oxyds can be made to combine with earthy substances, being too volatile.

Of the inflammables, sulphur alone is disposed to unite with mercury. Other inflammables are only employed to divide it. Sulphur may be combined with mercury, either by long and patient triture, or, more readily, by the assistance of heat, viz. by melting the sulphur, and pouring in the mercury warm, and stirring well. The compound in either case is of an intensely black colour;...hence, probably, called *æthiops*. When prepared by triture alone, the mercury is gradually divided and disappears; the mixture becoming grey and blackish. But although the mercury appears to

be perfectly incorporated with the sulphur, it does not acquire the full black colour until it has been kept for some time, especially if kept warm. Indeed, I find that the union by trituration is rendered at least three times more expeditious, and the combination more perfect, by a heat just enough to make the sulphur emit a sensible smell. Perhaps a little more heat would still improve the process. But still, after the longest keeping, the mercury and sulphur are more easily separated than when mixed by fusion. When the mixture is made by heat, they are more perfectly combined. But if they be made too hot, heat and flame are produced, seemingly by a sudden extrication of heat in the very act of union. This again arises from two causes: *1st*, The compound may have a less capacity for heat than the sum of the ingredients. *2dly*, In the act of combination the mixture becomes stiff, and sometimes hard. The heat, therefore, which makes an ingredient in their fluid forms, as latent heat, now emerges in sufficient quantity to kindle the sulphur. One part of sulphur is capable of forming a perfectly uniform æthiops with five, or six, or even seven parts of mercury. They are united together in this proportion for obtaining another preparation of mercury, viz. CINNABAR, or VERMILLION, by a brisk sublimation, in oval or oblong vessels of coated glass, or of earth.

This preparation forms a very considerable manufacture, chiefly carried on in Holland, to supply the market with the great quantity used in painting, and for medicinal preparations. And the descriptions given by authors of approved processes are numerous, and have considerable varieties. The most valuable property of the compound is the richness of its colour. When this is very deep or full, a moderate quantity of this expensive article bears dilution with a great deal of other colour. The fulness of colour corresponding also to its purity, becomes a general test of its goodness. The attention of the artists is, therefore, chiefly directed to this circumstance. It is found best to use an æthiops prepared by fusion. That obtained by trituration and digestion is apt to separate, in part, in the sublimation. Stahl's process, or that in the London Pharmacopœia 1788, seems to me the easiest and best.

The mercury is made hot, and poured into the melted sulphur, and the mixture carefully stirred. The flame should be extinguished by covering the mouth of the pot. The compound is then powdered and sifted, and rammed into an oval shaped vessel, so as to fill one-third of it. This is set in sand up to the neck; and has its mouth open, in order to allow the escape of a fuliginous vapour of uncombined materials.

When these fumes are condensed, they form a mass as black as pitch. It is composed of the superfluous sulphur: and this is blackened by a small quantity of the metal loosely combined with it. The sublimation is carried on with a brisk heat: and it produces a very good cinnabar. Beaumé says that two or three subsequent sublimations greatly improve its colour.

The sublimate is a solid cake, of a blood red colour, which grinds to a red, so much the brighter as it is more levigated. It may be made so fine as to become too pale. Chemists have wondered at this red colour, imputing it to some kind of oxydation: and indeed an experiment of Lemery's seems to confirm this. Vitriolic acid renders it white, and fit to afford turbith: and the operation is accompanied with effervescence. Now we know that the acid does not attack it till it be oxydated.

Hoffmann mentions a process by which he produced cinnabar without sublimation. He mixed running mercury with the volatile tincture of sulphur, that is, the compound of sulphur and volatile alkali. The mixture was long agitated violently. It soon became black, and at length grew a beautiful red, and a perfect cinnabar. Beaumé describes the same phenomenon as a discovery of his own.

Mercury is also said to be affected by the fat oils. In particular, it is said to acquire some ductility, if poured boiling hot into lintseed oil. I have not observed any thing of this sort; nor can I indeed have any notion of the ductility it can acquire. A solid that is brittle or friable may become ductile: a fluid cannot. It may be rendered sluggish, clammy, and perhaps viscid or tough, like melted glass, or sealing wax. But I have never observed this change produced on mercury by the treatment now mentioned.

All these combinations of mercury with sulphur are decomposed, and the mercury revived again, by distillation with quicklime, fixed alkali, iron filings,....all of which retain the sulphur. The mercury obtained from cinnabar, is thought to be the purest that can be had: and that obtained by means of iron filings is thought to excel the rest. I am sensible of its having a more perfect colourless brilliancy. Its density is also the greatest.

Relation to other Metals.

Mercury unites with all the metals except iron, arsenic, and platina. With the regulus of antimony, indeed, it unites very imperfectly, as we shall shortly see. And its more intimate union with the other metals will also be considered in their places.

Although arsenic does not unite with mercury, it affects the mercurial compounds, and is itself affected in a particular manner. If reguline arsenic be heated with twice its weight of the mercurial muriat (corrosive sublimate) in the way of distillation, the vapours condense into an oil-like liquor; part of which grows gelatinous, and almost like very soft butter which has been melted, being grumous or a little granulated, which I take to be an incipient crystallization. When this has finished, the vapours condense into metalline quicksilver.

This is a curious process. Neither the mercurial muriat, nor the regulus of arsenic, are so volatile as this compound: and the regulus is not so volatile alone as mercury is. The fluid and gelatinous matter are a compound of arsenic and muriatic acid. Water decomposes it in the same way as it does other metalline salts; that is, it separates it into two parts, one of which is nearly in the state of an oxyd, and the other contains this oxyd dissolved in the acid. This oxyd is an intermediate state between that of the arsenical acid and an arsenical oxyd.

I may remark on this occasion, that mercury clears the acid of arsenic (white arsenic) from sulphur and other inflammable matters which frequently make it foul. With the sulphur it forms an æthiops, which yields cinnabar in the usual way. I do

not see so well how mercury can separate the other impurities: and it is the more remarkable, because all other metals (silver and gold excepted) render arsenic foul.

I may also remark, that all the metals, when they decompose the muriat of mercury, form the same kind of butter-like compound: and it is most violently corrosive, destroying all organized bodies in a minute. Leaks in the distilling apparatus are, therefore, productive of the most fatal consequences to the operators.

Mercury is susceptible of mixture, in some manner, with all the other metals. And such mixtures, called *amalgamas*, are of different consistency, according to the proportion of the ingredients. If there be little of the other metal, they are fluid; if more, they are soft, like paste or butter. If there be less mercury than an equal weight, they form a sort of solid, more or less brittle and friable, in proportion as there is more or less mercury. The colour of these mixtures is always white. In amalgamas that are very soft or fluid, the mercury is in two different states. Part of it is fluid, and nearly pure. The other part is united to the metal in a solid form, in the same manner as water is united to salt in crystals of salts. This solid matter, composed of the metal and part of the mercury, is felt like gritty grains in the amalgam: or sometimes it actually forms oblong crystallizations in it. Thus, if we dissolve gold in boiling mercury, so as to form a soft amalgam, and then allow it to cool, the gold crystallizes or concretes with part of the mercury into spicular concretions, which are felt by the fingers. Hence amalgams, if fluid, may have part of the mercury imperfectly separated by expression through leather; but long triture, or long digestion, seems to produce more intimate union. It can be separated, however, by distillation.

Upon the discovery of these preparations of mercury, in mixture with the different metals, have been founded the arts of separating gold and silver, but especially gold, from their matrices, (of which hereafter); also the art of foiling glass for mirrors; and that of gilding silver, copper, or brass.

The process for foiling glass mirrors is performed in the following manner. The glass is laid flat on a very smooth and

firm table. A small border is made all round the edges, to hold in the mercury. The glass is then wiped very clean; and sometimes rubbed over with a piece of soft leather, on which a little amalgam of mercury and tin has been spread. It is then covered all over with tinfoil; and mercury is poured on it, till the border is full. The mercury penetrates the tinfoil, and makes it lie close to the glass, like a wet cloth. Indeed mercury penetrates the tinfoil just as water penetrates and softens a cloth. When this has remained some time, the mirror is slowly raised on one edge, that the superfluous mercury may run off; and it is allowed to stand in that position some days. Thus all the mercury not combined with the tin gradually subsides to the lower edge, leaving only what is necessary for keeping the tinfoil adhering to the glass plate.

Glass globes are coated on the inside, by warming them very much, and pouring in some fluid amalgam, which adheres to the glass like water. By turning the globe round and round, the whole inside may be thus smeared with the amalgam, so as to look like a metal globe highly polished. But when held between the eye and the window, we discover that it is covered only as with a cobweb of the metal.

Silver and brass are gilded by smearing them with an amalgam of mercury and gold. This makes them as covered with silver. The piece is then put into an oven: and the heat evaporates the mercury, leaving the gold adhering to the piece, in the form of a dirty brown powder. This is now gone over with a fine burnisher, made of steel or of hæmatites, highly polished. This flattens down all the particles of the gold, spreads them out, and causes them to adhere, while it also polishes them. Copper and brass acquire a skin that is undistinguishable from gold. But this gilding on silver has always a brown colour, very distinguishable. Moistening the surface of the piece with aquafortis causes the gilding to be more uniform and adhesive: for whenever the mercury touches the wet surface, the metalline nitrate adhering to it is decomposed by the copper: and some mercury is left on it in a metalline state. The buttery amalgam unites with this very readily: and when the mercury is expelled by heat, the gold remains. Without this precaution, parts of

the surface refuse to let the amalgam attach itself to them. In consequence of the same properties, it may also be applied to some useful purposes in medicine and surgery; to dissolve a lead ball, a piece of leaden tube, or probe, in the bladder; also to take off a ring from a swelled finger.

All the metals exhibit a peculiar appearance, when employed to decompose the muriat of mercury. They unite with the acid in a soft buttery form. Another general circumstance in this decomposition is, that this butter is more volatile than the muriat, and even than the mercury, although the metal employed may be much more fixed. These compounds will be mentioned in course: but I thought it proper to make you notice these general characters.

Ores, or Origin.

Mercury is scarcer than gold. The only mines are at Almaden, in Spain; Idria, in Hungary; in the Dutchy of Deux Ponts; in Friuli, in Italy; in the East, and in the Spanish West Indies. Small quantities are sometimes found in France and Britain. Virgin, or fluid mercury, is often interspersed through other minerals. But the most common ore is cinnabar. The fluid mercury is oftenest found where cinnabar is most abundant. I think that the rarity of this metal, and even of small portions of it mixed with other ores, is an abundant proof that there is no such thing as a *mercurial principle*, the basis of metallization. Were it so, we should find imperfect metals very frequent, and in different stages of the progress, to the state of perfect metal.

The account given of the chemical properties of mercury makes it easy to perceive how we shall obtain it from its ores. All the processes, performed at all the mines, are distillations, managed with more or less art, and varied according to the nature of the ores. Even where found in a fluid form, it is generally in globules, too small to be separated by the hand; or by pounding and washing. It is much easier to do it by distillation. The cinnabar ores are generally mixed with so much calcareous matter, that no addition is necessary for separating the sulphur. When this is not the case, (as at Deux Ponts,) slaked

lime is mixed with the ore in the retorts. These are placed in a row, in a long furnace like a gallery. Their necks project through holes in the sides. To these are fitted receivers containing water, into which the mercury falls. At Almaden in Spain, a long row of earthen aludels go from each retort, down a gently sloping terrace, and then up a similar terrace; and terminate in a chamber, having a concave floor, and a tall chimney. The distillation is forced by considerable heat: and the vapours condense in the aludels, both in the descent and subsequent ascent. What are not condensed there, are condensed in the chamber. The sloping position of the aludels causes the mercury to run out of the higher into the lower, on both sides of the valley formed by the two terraces: and all of it collects in the aludel at the bottom. This one has a short pipe, or neck, in its under side, which is plunged into a hole cut in the stone which forms the gutter between the two terraces. The gutter is filled with water. From this construction, it is plain the aludels have no communication with the air, except by the chamber. The distilled mercury, therefore, runs out of the lower aludel of each row; fills the hole in the gutter; and then runs over, with water above it, into the gutter. This has a very small declivity towards one end. The mercury, therefore, runs along this gutter into a gutter at one end of it. Thus the distillation is carried on with rapidity: and there is no risk of bursting the vessels, or of the vapour escaping by any leaks.

Medicinal Preparations of Mercury.

The very great activity of mercury on the human body, and its effects when exhibited as a medicine, are so remarkable in the treatment of many diseases, that physicians have turned it into almost every possible shape: and the mercurial preparations are almost innumerable. In this respect it has but one rival in the fossil kingdom, viz. antimony, the preparations of which are no less various. To pass them by would be highly improper. But to describe them all would require a winter's session; and would be no less improper. I must content myself with considering them in two points of view. I shall describe such of them as indicate any singular chemical property of mercury

and antimony, by which your chemical science is improved. I shall also take particular notice of any connection or dependence that I can discover between the medicinal effects of the preparations, and the general chemical resemblances that may obtain among the methods of preparing them. This will direct the medical chemist to such treatment of the metals as are the most likely to produce the desired medicinal effect. Thus will the philosopher be instructed, and the artist directed. (*See note 26. at the end of the Volume.*)

GENUS V.....ANTIMONY.

AFTER mercury, I shall next consider the brittle and volatile metals, which on account of their wanting ductility, are called imperfect, or semi-metals; and antimony (*stibium olem*) being one of these, we shall take it first. It is the one to which the chemists and physicians have paid the greatest attention, torturing it into an endless variety of forms.

ANTIMONY is a dull silver-coloured metal, of the specific gravity 6,7. Its surface exhibits facets, and a star-like figure. This appearance proceeds from a crystallization, or arrangement of its parts in cooling. It is totally destitute of malleability, and can easily be beaten to powder. It is possessed of fusibility and volatility. The vapours of it calcine to a white smoke, and condense on the surface of any cold body exposed to them. Or if they are collected, and somewhat confined, in the cavity of a vessel applied to receive them, they condense into a matter composed of minute spicular crystals, very like snow, or flores benzoini, called *nix antimonii*,....snow of antimony; or by some chemists, silvery flowers,....*fleurs argentines*. You may see all these phenomena by heating a little bit of antimony with the blow-pipe on charcoal. There is here an evident inflammation. The white smoke is partly composed of an oxyd, formed by the action of the air, and it adheres to any cold body in form of a white powder. It is pretty highly oxydated. But when the heat of the mass abates, and the vapours arise more slowly, and are less calcined, a part of them condenses on the surface of the metal itself, appearing like a covering of snow.

We can also calcine this metal with an inferior heat, so as not to convert it into vapour. It must be beaten to powder, and spread out in a broad and shallow vessel, and exposed to a very gradual heat. The surface of the metallic particles soon becomes tarnished and dusty : and they are by degrees converted into a dust, or earthy-like powder ; first dark grey, or ash-coloured, but by continuance of the calcination, yellowish, and at last white.

These calces, or oxyds, are remarkable by proving all volatile, if exposed to the action of heat and air at the same time : and when the vapour of them is condensed by cold and a proper apparatus, they form the silvery flowers.

Some chemists have thought that there was a resemblance between antimony and arsenic. And they certainly resemble one another in this respect, that the calces of both, when in a state of moderate calcination, can be converted into vapour very easily. But the calx of antimony differs from white arsenic in this point, that whereas white arsenic will evaporate in closed vessels, or by the action of heat alone, without requiring the assistance of fresh air, the calces of antimony will not evaporate, except when exposed to the action of both heat and air. If the access of fresh air is excluded, they endure a very violent heat. And the effect of the heat in this case is to melt them into a glass. They melt the more easily, the less they have been calcined. And the glass thus produced has always a deep ruddy brown yellow colour, which is so much the deeper and darker, in proportion as the calx was less calcined.

All such calces or glasses are reducible to a metallic state ; the less calcined, however, the more easily and completely. The reduction is performed by fusion with charcoal dust, or black flux, or fixed alkali and soap. So far of the effects of heat.

The greater number of the acids can be made to act on antimony in one way or another. Some attack it readily in its metallic state ; others better when it is slightly or moderately calcined. But when it is greatly calcined, few of them are disposed to unite with it. Dr. Pearson, in his dissertation on James's powder, (*Phil. Trans.* 1791.) gives an account of a series of experiments made with the view of comparing their different solubility. And it appears that the degree of calcina-

tion has a very steady connection with the solubility of the calces.

The action of the sulphuric acid on antimony very much resembles its action on mercury. It must be strong and hot. The action is attended with effervescence and the eruption of fumes of sulphurous acid; and towards the end of the process, actual sulphur. The effervescence being frothy, it is very troublesome, rising in the vessel and running over. After some time, this ceases, and the liquor may be said to boil rather than to effervesce....it is still however the same elastic gas which it emits. At length, the metal is completely taken up, or changed: and we have a white precipitate, and a solution of a sulphat of antimony. The precipitate is nearly a perfect oxyd. The solution will not crystallize by evaporation: but when reduced to a dry mass, it immediately deliquesces again. The solution may be decomposed by alkalis; and gives an oxyd extremely difficult of reduction.

Nitric acid can scarcely be called a solvent of antimony; for its form never disappears. After remaining some days in the acid, the metal is only found divided, swelled up, and covered with bumps like colli-flowers, just as in its calcination. The laminæ are separated, and the interstices filled with a white oxyd. All this is accompanied by a great change in the acid....red fumes are emitted in abundance: and the liquor acquires a green colour. In short the acid is decomposed. When the materials are examined, we find the metal completely changed. There is a matter lying at the bottom, which, on examination, is an oxyd of the metal, with some excess of oxygen. The liquor contains a nitrate of antimony. Water causes some precipitation: and the remainder is the solution of a very deliquescent salt, which can be decomposed by an alkali. This precipitates an oxyd of antimony, which it is very difficult to reduce to the metallic state.

Muriatic acid acts very slowly and languidly on antimony; but it acts on it, and dissolves it with a slight effervescence. If, however, it be digested on antimony, it dissolves it, and retains it, when nitric acid, either strong or weak, is added to the solution; thus, making it evident that it attracts the metal. With

care, the muriat may be made to crystallize in spiculæ: but it is extremely deliquescent.

The action of the marine acid on antimony is much promoted by adding to it a small quantity of nitric acid. When this mixture is poured on the metal, we have at once a brisk solution, and the copious eruption of nitrous fumes, even although the quantity of nitric acid should not amount to one-tenth of the muriatic. It is better however to add one-fifth. This mixture dissolves a considerable quantity: and the muriat yields a very deliquescent salt, which is also very fusible and volatile,... and is parted by water, like the nitrate, yielding an oxyd, and retaining the true muriat: and this may be decomposed by an alkali.

These phenomena, exhibited by antimony in the nitric and muriatic acids, are easily understood. The nitric acid contains oxygen very weakly united. Part of it unites with the antimony, and the oxyd, being very little soluble in water, lies at the bottom of the liquid. The fumes are nitrous gas. The muriatic acid has its ingredients united too firmly; and does not therefore act on the metal without long digestion, and even then acts feebly. But a little nitric acid supplies it with as much oxygen as suffices for the oxydation of the metal: and the fumes which break out are nitrous. Indeed the simple addition of colourless nitric acid to the muriatic immediately emits the fumes. When we have got the metal into the state of an oxyd, the solution goes on apace. In confirmation of this explanation, I must observe, that the oxygenated muriatic acid dissolves the antimony with great facility, and produces the very same compound with that just now described.

This, however, is not the usual or most complete way of effecting a combination of antimony with the muriatic acid. The processes in common use are different, but they depend on the same principles.

In one of these processes we mix sixteen parts of corrosive muriat of quicksilver with six parts of the metal of antimony, both in powder, and apply to this mixture a subliming heat in a retort and receiver. The metal is in this case both oxydated, and at the same time combined with the dry and strong muriatic.

tic acid of the corrosive muriat of mercury. The oxydation is effected by the mercury, which being itself in a highly oxydated state, or combined with a good store of oxygen as well as with acid, transfers both the oxygen and acid at the same time to the antimony, which has a stronger attraction for them both than the quicksilver has. The antimony therefore is both oxydated sufficiently, and combined with the acid,...the quicksilver resuming its metallic form. In this, as well as in the similar process with arsenic and mercurial muriat, the mercury requires a greater heat to raise it in vapour than the antimonial muriat; and this last is even more volatile than the mercurial, though antimony is more fixed than mercury.

The new compound differs from the corrosive muriat of mercury by being more easily melted than volatilized, whereas the corrosive mercury is more volatile than fusible. The antimonial caustic or corrosive, therefore, rises in vapours, which condense first into a fluid matter, on some of the cool parts of the retort: but when they reach parts still colder, the fluid matter quickly congeals into a solid icy-like substance, which can be easily melted again, and congealed at pleasure, melting with a gentle heat, almost like tallow or butter. Hence the ancient chemists gave it the name of *butter of antimony*. Its colour is dark at first: but, by rectification, it becomes white or colourless like ice; a little superfluous metallic matter and some impurities being thus separated from it.

When we make further experiments with this compound, we learn that it has a strong attraction for water. A very small quantity of water dissolves the greater part of it, or reduces it to a liquid form; and it readily attracts so much water from the air, if it be exposed in open vessels. As it is more convenient to keep and use it in a liquid form, it is commonly sold liquid, by the name of *antimonial caustic*. In the last editions of the London and Edinburgh Pharmacopœias, this compound is called *antimonium muriatum*. It is very acrid or corrosive with respect to animal and vegetable substances. A little of it applied to the skin very soon burns or destroys the part. Whence antimonial caustic is employed to destroy fungous excrescences from ulcers or other parts.

Water, added in large quantity to this compound, affects it in the same manner as it does the sulphat of mercury. The water attracts and dissolves the acid, leaving the metal in the form of a white oxyd, which, although washed with repeated additions of hot water, retains still a small part of the acid. It is called *powder of Algarotti*, from the name of an Italian physician, the inventor; also *mercurius vitæ*, though it contains no mercury. Nor does it contain any acid, if prepared with proper care. It should be a pure oxyd, pretty copiously oxydated.

Antimony unites also with the vegetable acids. The acetous and tartarous acids, and the acid of vinous liquors, dissolve it, and become violent emetics. But these acids dissolve it much better when it is slightly oxydated. They are medicines of great activity; and should therefore be very accurately prepared. Unfortunately, it is very difficult, if possible, to reduce them to the same strength when prepared by different processes. And the physician prescribing his dose by the effects of a preparation to which he has been accustomed, may produce very unexpected effects, when the same dose is given of the medicine otherwise prepared. I think that the precipitate from the antimonial muriat has a greater probability of being uniformly the same than any other oxyd of metal. It is, therefore, a good basis for these vegetable additions.

Of the neutral salts, only nitre and sal ammoniac act upon antimony. The first deflagrates: and the heat of deflagration volatilizes some of the metal. We thus get an oxyd whiter and less fusible in proportion to the quantity of nitre. Nitre two parts, to antimony one part, gives an oxyd very white and unfusible. The alkali of the nitre, mixed with this oxyd, is called *reguline caustic*.

Sal ammoniac presents nothing particular, or different from its action on metals in general.

Of the inflammable substances, sulphur readily unites with this semi-metal in the fire, and forms a fusible compound, which bears a great resemblance to the semi-metal by itself. But the sulphuric compound has less brightness, and a darker colour, and more slender crystallizations.

The sulphur can be separated, and the metal recovered in its pure state by different processes; as,

1st, By roasting the sulphurated antimony, so as to evaporate the sulphur, we get the metallic matter in the form of an oxyd, which retains very little of the sulphur, and may be reduced to the metallic state by melting it with black flux. The first part of this process requires patience and attention, on account of the volatility of the metallic matter. I shall take further notice of it hereafter.

2dly, Another method, which is shorter, is to melt the sulphurated antimony with an equal, or half its weight of black flux. The alkali joins the sulphur: and a part of the metal in its pure state separates to the bottom of the vessel. But by this method we obtain only a part of the metal. A considerable part is dissolved by the alkaline sulphuret, and if a pure alkali is used in place of black flux, it dissolves the whole.

3dly, We can separate the sulphur by other metals, many of which have a stronger attraction for it than this semi-metal has. Iron is commonly used, either in filings, or small nails, or the scraps from the tinplate-workers. A strong heat is necessary. Thus the antimony settles to the bottom: the sulphurated iron flows uppermost; and is separated more easily, if some saline matter has been added to promote the fusion.

When this metal happens to be combined with sulphuret of alkali, it can hardly be separated again, except in this manner, by melting the compound with other metals which have a stronger attraction for the sulphuret. Other metals thus employed to separate the antimony from sulphur, or alkaline sulphuret, are liable however to mingle with it a little, and to make it impure. For it is disposed to mix with all other metals, if properly applied to them with a melting heat. Iron appears to have the strongest attraction for it. With all the tough metals, it produces compounds more or less brittle. And besides this effect on iron, it deprives the iron of its magnetic qualities and dispositions to be attracted by the magnet. No other metallic substance affects iron in this manner.*

* I find that less than three parts of antimony to one of iron will not destroy the magnetism of the iron....EDITOR

The method of separating it from the different metals is various, according to the nature of the metal with which it is joined.

From gold or platinum it is separated by evaporation, or the action of heat and air. From other metallic substances it is best separated by the addition of sulphur, or, in some cases, by scorification, as from lead.

Such is the chemical nature of this semi-metal. It is one of those which are produced by nature in large quantity in some places; and the ore of it is every where nearly of the same kind. Sometimes, though rarely, it has occurred in a state of purity. But such specimens are very rare, and the quantity trifling. The most common state in which it is found is combined with sulphur: and I believe there is some variety in the proportion of the sulphur to the metal in the different ores. Most of them contain a little arsenic. Its presence is easily known by the white and silvery appearance of the ore, and by the orpiment which it yields by sublimation. The appearance of these ores is very like that of the artificial compound of the metal and sulphur. And the only operation which the metallurgists perform with these ores, before they send them to the market, is to separate from them the earthy and stony matters or matrix, which happens to be combined with them.

This is done by the process named in metallurgy *Eliquation*. The crude antimony is put into earthen pots, pierced in the bottom. These are set upon other pots buried in the ground. The fuel is thrown in around the pots; and the fire kept in a uniform state, by the judicious structure of the furnace. When the ore is fused, it runs into the lower pots, and the earthy matters remain in the upper ones. It is frequently moulded in truncated conical loaves. As this is the only operation performed on this mineral to fit it for sale, it comes into the hands of the chemists and druggists in this state, in which the metal is still combined with sulphur, and may be considered as yet in the state of an ore. They were accustomed to call it *crude antimony*, or, simply, *antimony*. And the pure metallic part, when separated from the sulphur, has been commonly named *regulus of antimony*. But the later chemists give the name of *antimony* to the pure

metallic part ; and to this compound, that of *sulphurated antimony*, or *sulphuret of antimony*.

It is therefore by working on this sulphurated antimony, or crude antimony, as it is called, that most of the preparations of antimony are produced, in the art of pharmacy. By what you know already of the nature of its two constituent parts, I mean sulphur, and the metallic substance which I have already described, you will now easily understand the changes it undergoes by the action of heat and air, or of different solvents, and other active substances.

Preparations of Antimony.

Before I begin to describe the different preparations of this mineral, I beg leave to make a remark upon the whole of the subject, which will assist you to understand how these preparations differ from one another, in point of efficacy as medicines: for the general purpose of preparing crude antimony is to give it more or less medicinal efficacy, to make it either a strong and powerful remedy for some purposes, or one that shall be mild and safe for others.

In the first place, there is good reason, from experience, to believe that antimony never acts as a medicine, except when dissolved or combined with an acid, either before it is taken into the stomach, or in consequence of its finding an acid there with which it unites. But in crude antimony, the metal neither is already united with an acid, nor is it much disposed to join with the weak acid which alone it can meet with in the stomach. The sulphur with which it is joined, and the uncalcined state of the metal, are unfavourable to its being easily dissolved by a weak acid. In order to make it easily soluble in the acid of the stomach, we must separate more or less of the sulphur, and *calcine* or oxydate the metal to a *moderate degree*. I say a moderate degree: for if we oxydate it very much, we again diminish its disposition to be dissolved. By taking away, therefore, more or less of the sulphur, and moderately oxydating the metal, we produce preparations which are capable of acting very powerfully. But their action is not always the same, or in proportion to the

dose. It depends on their meeting with acidity in the stomach, which is not always present there in sufficient quantity to give them all their efficacy.

The surest way to reduce antimony to a form in which it will act equally and strongly (at least so far equally as the different constitutions of different patients will permit), is to separate the sulphur, and combine the metal with an acid, so as to give it a saline soluble form before it is thrown into the stomach.

And now, having premised these remarks, we shall proceed to describe the different preparations, in the order in which they are arranged in the table of them which I have put into your hands. (*See Note 61. at the end of the Volume.*)

The first is the *antimonium præparatum*, in both our pharmacopœias. It is crude antimony, reduced to a very fine powder, simply by triture and elutriation with water. I remarked already, that crude antimony has but little efficacy as a medicine, or is an exceedingly mild one. This is a consequence of the state of the metal in it, which is neither already united with an acid, nor much disposed to unite with the acid of the stomach, not being prepared by any degree of calcination, and having also the sulphur adhering to it. The *antimonium præparatum* is, therefore, never given when we propose to vomit or purge. It is only used to promote perspiration, or to excite the other evacuations so gently that its effect is hardly perceived, and that the use of it may be continued constantly for some time: and to make it act even thus, the greatest levigation is necessary. The *antimonium præparatum* is, therefore, crude antimony, reduced to this state of a very fine powder ready for use. Kunkel, an eminent German chemist, is said to have cured himself of a rheumatism with it. I once had an opportunity of perceiving that it sometimes excites nausea, and expels worms: a proof that it is not quite inactive. In preparing it, we must be careful to avoid the base or broader end of the conical loaf into which it is moulded for sale. If any impurities, or admixture of other metals be in the mass, they are in this upper part. They scorify with part of the sulphur; and being thus lighter than the rest, float above it.

The next preparations are those produced by the action of heat and air.

When crude antimony is exposed to heat suddenly, the most of it evaporates, especially if air be admitted. This is to be expected; as both the metal and sulphur are volatile substances. Its evaporation is attended with some inflammation, visible in the dark. By careful procedure, the sulphur may be completely dissipated by roasting the powdered antimony. No suffocating smell will be perceived. A sudden increase of heat would mar the operation, by melting the antimony, and thus diminishing its extensive surface. As the operation advances, we may increase the heat without danger of melting. This may be continued till all the sulphur is expelled. The metal now begins to attract oxygen, and grows grey, and at last white; and in this state is a pure oxyd. Thus you see that by terminating the process at different periods, we shall procure the metal in very different states. It is therefore a matter of importance that it be conducted in a very uniform manner.

There is the same, or perhaps a greater variety, when the heat is so great as to cause the sulphur to attract oxygen. In this case we have suffocating fumes, &c.

The only preparations which have been produced by the action of heat and air are, the *flores antimonii sine addito*, the *calx antimonii*, the *vitrum antimonii*, and the *vitrum ceratum*, (*Pharm. Edin.*) prepared from the vitrum.

To prepare the *flores antimonii sine addito*, the sulphuret is put into a crucible, or unglazed earthen vessel. A set of aludels are set on it: and a pipe is inserted by a proper opening in the side or lip of the crucible. The fire being kindled, and having grown pretty strong, the fumes begin to arise: and then a pair of bellows are applied to the pipe; and a gentle stream of air is made to play on the surface of the materials, but in the most gentle manner possible. The metallic and sulphurous fumes now rise; and are condensed in the different aludels. The sulphur of the flores, being the most volatile of the fumes, rises highest, and the oxydated flowers are contaminated by it so much the more as they rise higher, or rather they rise so much the higher as they con-

tain more sulphur. The artificial stream of air cannot be managed with such delicacy as to preserve that regular gradation which may be obtained in a small quantity sublimed without the blast. This preparation, therefore, is unequal and uncertain; and is now disused.

Vitrum.....In making the glas of antimony, we begin by separating the sulphur, or the greater part of it, by the action of heat and air, and at the same time oxydate the metal to a moderate degree.

Both these objects are attained by performing the operation practised with ores of metals to free them from sulphur. It is named *ustulation*. The operation of ustulating sulphurated antimony is difficult on account of the fusibility of this mineral, and of the volatility of its metallic part.

To diminish fluidity, some add charcoal dust. Others add common salt, which is easily separated afterwards by water.

But the common way is to ustulate it without addition.

It necessarily happens in this operation, that the metallic part is oxydated, while most of the sulphur is evaporated. And, if the operation be properly managed, we have an oxyd of the metal of a grey or ash colour, moderately oxydated, and with very little of the sulphur remaining in it, and therefore in a condition to be easily melted into glass: for we have learned by experience that the presence of a little of the sulphur greatly promotes its melting into glass.

It is therefore by simply melting an oxyd of antimony, prepared in this manner, that the glass of antimony is obtained.

Vitrum ceratum is prepared (in order to mitigate the action of the vitrum antimonii) by kneading the pulverised glass of antimony with bees wax, and then burning away the wax.

The next preparations of antimony in the table are those prepared with alkaline salts.

The fixed alkalis act readily on crude antimony, on account of the sulphur which it contains, and with which they have a strong disposition to join.

Of this we have examples, when we apply these salts to the crude antimony, either in the dry way by fusion, or in the humid way in the form of watery solution. They act most readily and powerfully when applied in the way of fusion. The alkali joins itself to the sulphur, and forms a sulphuret of potash,....a compound which has great power to act on the metals in fusion, and to dissolve even those with which sulphur alone cannot be combined. The metallic part of the antimony, therefore, does not separate, or very seldom, and in small quantity only. Commonly the whole mixture melts into one uniform vitrified-like mass. If one part of fixed alkali and five of crude antimony are melted together, and some common salt added, which promotes their fusion, we obtain a dark coloured vitriform mass, once known under the improper name of *regulus antimonii medicinalis*. It is easily ground to powder; and gives a powder of a reddish brown, or a sort of chocolate colour, which is insipid on the tongue, and not soluble in water. It is a very mild preparation; but has a little more efficacy than the antimonium præparatum.

Larger proportions of alkali form masses which prove more or less soluble in water. Those which contain one of alkali to two of crude antimony are soluble in hot water, not in cold. With large proportions of alkali, they are soluble in cold water as well as in hot. With two of alkali to one of crude antimony, they are even deliquescent, or attract humidity.

The most proper name for all these compounds is alkaline sulphurets of antimony.

When we apply water to them, to dissolve those that are soluble, none of them are dissolved completely. There is always a separation of a reddish or brownish sediment, which is more plentiful in proportion as there is less alkali in the composition of the mass. This sediment is formed by a part of the antimony: and it is some of the more metallic part which thus separates. The rest, which in consequence of this separation is more sulphurous, and has more alkali combined with it, remains dissolved.

Beside the way by fusion, I observed before, that we can form compounds of this kind in the way of watery solution, or, according to the language of the chemists, in the humid way.

Though the alkali, in whatever manner applied, acts by its attraction for the sulphur chiefly, it dissolves in this way also the greater part of the metal. It continues adherent to the sulphur, and is dissolved along with it. The solution, therefore, which we thus obtain, is a solution of an alkaline sulphuret of antimony, which is rather more easily decomposed, and requires more water to keep it dissolved, than a plain sulphuret of potash: and the cause of this is, that the metal, by its attraction for the sulphur, diminishes a little the cohesion of this last with the alkali.

We quickly decompose this sort of sulphuret, when we add an acid to the solution. This immediately neutralizes the alkali, and occasions the sulphur and metal to separate from it. While they separate from the alkali, they remain combined together, and form a powder or precipitate of a deep orange or red colour, called formerly *sulphur antimonii auratum*, now *sulphur antimonii præcipitatum*.

In this preparation, the antimony, although it retains much the same principles as in its crude state, is much more active, however, as a medicine. The dissolution it underwent has divided the particles far more subtly than can be done by any mechanical division or triture. And the close union of the sulphur and metal was diminished during the combination, in consequence of the action of the alkali on the sulphur. The metal is therefore more disposed for being dissolved by the acids of the stomach, than it is in crude antimony.

But, in order to make the product of this process always equal, it is necessary to add the requisite quantity of acid for saturating the alkali, and precipitating the antimony all at once. If we add only a part, and collect the first precipitate before we add the rest of the acid, the first and second precipitates will be unequal. The first will contain more of the metal, and less of the sulphur, than the second precipitate; the attraction of the alkali being chiefly for the sulphur of crude antimony. It therefore quits it more slowly than it quits the metallic part.

When we take the potash in its common state of an imperfect carbonat, and dissolve the antimony by it in the same humid way, it acts much more slowly and with less power. And when the boiled solution is allowed to cool, it deposits again the greatest part of the crude antimony which it had dissolved, shewing thereby that the presence and assistance of heat is necessary to enable such an alkali to hold the crude antimony dissolved.

We have an example of this in the process for *kermes mineralis*.

This *kermes mineralis* is reckoned in France one of the capital preparations of antimony. It first attracted notice while it was a secret remedy in the hands of a Carthusian monk, who performed several surprising cures with it in the pneumonia, and other violent fluxions or congestions in the lungs. Upon inquiry it appeared that the monk had got it from one Ligerie, who was possessed of the secret, and who had learned it from Glauber, or from a scholar of Glauber's. The Duke of Orleans, then regent, was advised by the king's physician, to purchase the discovery of it at the king's expence, and make it public.* But the younger Lemery, in a memoir, inserted in the *Mem. de l'Acad.* for the year 1720, proves that this medicine was contrived, or at least the process for it published by his father, in his treatise on antimony; and that his father's process is rather better than La Ligerie's. The elder Lemery called it a *sulphur auratum antimonii*, and not improperly; for the *kermes mineral*, in whatever manner it be prepared, is very much, and almost precisely, of the same nature with the *antimonium*, or *sulphur antimonii precipitatum*, which was formerly named *sulphur auratum*. †

* *Ligerie's Process*.....Crude antimony broken small, four ounces; deliquium of nitrate of lime, one ounce; and water eight ounces. Boil the mixture two hours. Decant and filtre it while hot. While it cools, the *kermes* is precipitated. Add to the remaining antimony six drachms of the nitrate of lime, and eight ounces of water; repeat the boiling and filtrate. Repeat the last part of the process; collect the three precipitates; and edulcorate with water.

† The elder Lemery's original process is this.....Put into an iron pot five or six pounds of a solution of pure fixed alkali, with three or four times

Lemery's process, however, and the product of it, had been neglected, until it attracted notice as a secret remedy, and was purchased for the use of the public; and then it became so much an object of attention, that the most celebrated French chemists have exercised their ingenuity in throwing light on the process, and improving it.

A great inconvenience in La Ligerie's process is, that the quantity of kermes produced by each boiling of the materials is very small.

Geoffroy, who made many experiments to investigate the nature of this preparation, proposed a process by which it may be obtained in far greater quantity, and with incomparably less trouble.*

The precipitated matter, when well washed and dried, is a soft and tender powdery matter, of a deep brownish red, or rather a coffee colour.

The liquor from which it has been deposited, retains the greatest part of the alkali, together with a small quantity of the antimony adhering to it; but retains so much of the uncombined alkali, that, if boiled with more antimony, it dissolves it again, and by cooling, deposits a fresh quantity of kermes; and this after many repeated operations of the same kind.

This preparation is much the same with the sulphur precipitatum. It has a moderate degree of power as an antimonial.

Meuder, a pharmaceutical chemist of reputation, says that all depositions by cooling, from the warm washings of the hepatic

as much water. When the liquor boils, throw into it four or five ounces of finely powdered crude antimony. Boil the mixture a short time, stirring it with an iron spatula, and then filtrate it boiling hot through paper. It will deposit the kermes, which must be well washed, dried, and ground to a fine powder,....a grey powder remains, which is regulus which the hepar could not dissolve. The same alkaline liquor may be used several times.

* *Geoffroy's process*.....Two parts of antimony, and one of alkali, are melted together and pounded. This makes an alkaline sulphuret, soluble only in hot water. It is boiled with water, and filtered into a large quantity of hot water; and upon cooling, yields of kermes, three-fourths of the weight of the antimony.

In young Lemery's process, fine powder of antimony is boiled with the pure deliquium of nitrate of lime: and thus the whole antimony is dissolved.

preparations of antimony, may be distinguished from a *kermes mineralis* by the following marks :

1. The *kermes* is red ; and the others are brown.

2. *Kermes* act much more gently as a medicine. I may observe, that if the *kermes* be prepared by employing a caustic alkali, we have the *sulphur fixum Stabelii*.

And now, having enumerated the preparations of antimony obtained by the use of alkalis, as well as those produced by the action of heat and air, we shall next take those produced by deflagration with nitre, which are in some respects similar to those already described.

When crude antimony is mixed with nitre, and this mixture is set on fire, or thrown by degrees into a hot crucible or iron pot, there is more or less deflagration, according to the proportion of the nitre in the mixture. In this deflagration, the acid of the nitre, by its abundant oxygen, acts most violently on the sulphur, which it changes into sulphuric acid : and the greater part of this acid combines with the alkali of the nitre. But the acid of the nitre acts also more or less on the metallic part of the crude antimony, and oxydates it either moderately, or to a high degree, according to the quantity of the nitre employed. A number of preparations made in this way have been contrived, and highly recommended, at different times. I shall describe a few of them.

First, what Mr. Lewis calls *crocus medicinalis*. A mixture of one part of nitre and eight of antimony in fine powder, is projected into a red hot crucible. So small a portion of nitre can produce no sensible deflagration. It seems only to assist the fusion and solubility of the mixture. It breaks with a glassy fracture, is opaque, and has a surface like polished steel. It produces a mass of a deep purple colour, like that obtained from antimony acted on by a small quantity of alkaline salts. This preparation is also very similar in its degree of efficacy to the alkaline sulphuret, which was called *regulus antimonii medicinalis* : and indeed the same name of *regulis medicinalis* has been given sometimes to this preparation also. It is insoluble in water, and insipid.

In the other preparations of this kind with nitre, larger proportions of nitre are used, and produce more active effects: but the chief of them is the *crocus antimonii*, formerly named (often very improperly) *crocus metallorum*. (*Pharm. Lond.*) In this preparation, since the proportion of nitre (equal parts) is very considerable, the deflagration is very brisk, or rather violent: and the fusion does not require the crucible to be red hot in the beginning: the first projection may be kindled by a bit of lighted paper. And by properly timing the subsequent projections, the heat rises to a great pitch, and makes the whole melt very completely. The saline part is separated and thrown away: the vitrified metallic matter only being the useful part. It assumes a yellow colour when ground to powder, whence it has got the name of crocus. The nitre is partly converted into vitriolated tartar, and partly alkaliized. If the operation be managed so that all shall be fluid at once, the greatest part of the salt collects uppermost by itself. The metallic matter goes to the bottom semi-vitrified; but the glassy matter at the bottom is not perfectly free from salt. It contains, united with the vitrified matter, a small quantity of alkaline salt, produced from that part of the nitre which deflagrated with the metallic part of the antimony. And, besides this alkaline salt, there is even a very small portion of sulphur remaining united with the alkali and metallic oxyd. It was, therefore, some time ago, a practice to separate as much as possible this saline matter from the crocus, by reducing the crocus to a fine powder, and boiling it in water, which (after subsidence) being poured off, the crocus was dried, and was named *crocus lotus*. I find the most successful way of proceeding is, to deflagrate in a hot iron mortar set on the fire, projecting very small quantities, but in quick succession. Thus you will have a good fusion and separation, and a fine crocus without further trouble. *Crocus*, or *crocus Rolandi*, according to Meuder, is the deflagrated stuffedulcorated without previous fusion.

You will find great confusion in the names of these productions of antimony. It was formerly called, with the greatest impropriety, *crocus metallorum*. And you will find that the French writers, Lemery and Macquer, choose to call it liver

of antimony,...*foie d'antimoine*; and with as little propriety, gave it the name of *crocus metallorum* after it was washed.

The nature of this preparation, as a medicine, is similar to that of the glass, but rather inferior in violence.

When the dose of nitre is much farther increased, besides the complete destruction of the sulphur, the metallic part is more calcined: and this may be to such a degree, that its operation as a medicine is thereby diminished, as it becomes less disposed to unite with the acids found in the stomach. Such is the *antimonii emeticum mitius* of Boerhaave, viz. antimony, one part; nitre, two parts: such also is the *antimonium calcinatum*, (Lond.) viz. antimony, one part; nitre, three parts. The matter at first taken out of the crucible contains sulphat of potash, and a little unsaturated alkali. These salts are separated by hot water: and then we have the pure white oxyd. Four ounces of antimony yield five and a half ounces of the *antimonium diaphoreticum lotum Meuderi*, which is accordingly called *antimonium calcinatum*; as also *antimonium diaphoreticum*.*

The *antimonium ustum cum nitro* of the Edinburgh Pharmacopœia may be considered as similar to these preparations, only more active than the *antimonium calcinatum*. The crude antimony is first roasted to a calx; then mixed with an equal quantity of nitre, and melted, or made red hot one hour; and thenedulcorated with water. It was meant to be an imitation of James's powder; the process being copied from the specification of his patent. But either Dr. James changed his process afterwards, or gave a false or disguised description of it: for lately it has been clearly proved to be very different, by Dr. Pearson's experiments, read to the Royal Society of London, in 1791, and published in the Philosophical Transactions. It now appears to be a combination of antimony with the acid of phosphorus, or rather with a phosphat of lime. Nitrous acid

* Geoffroy observed a singular phenomenon in his operations on this medicine. Having ground an ounce of it with two ounces of black soap, he roasted the mixture to a coal; and then ground it coarsely with another ounce, and exposed it to violent heat, in a covered crucible. Five hours after all was cold, he took off the cover. The mixture instantly took fire: and being very spongy, so that the air had easy access to the interior parts, it took fire all over, and dissipated with a terrible explosion.

dissolves the phosphat ; and the phosphoric acid remaining in the solution is easily discovered, by means of a solution of mercurial nitrate, or by a nitrate of lead. The antimonial oxyd is discovered by means of muriatic acid, and precipitation from it by water.

Dr. Pearson's judicious examination led him to attempt the preparation, on the principles arising from this analysis. And his imitation is so undistinguishable from Dr. James's powder, that it is adopted by the London and Edinburgh Dispensatories, under the name of *pulvis antimonialis*, or *antimonium calcareo-phosphoratum*. Equal weights of antimony and horn shavings are calcined till of a very fair grey colour, and then kept red hot in a coated crucible, for two hours ; and when cold, reduced to a fine powder, which when well prepared, is of a pure white, or has a slight cast of yellow, but not inclining to brown.

Preparations with Acids.

In general, the acids do not act so well on crude antimony as they do on the regulus, or pure metallic part of it. The sulphur, in some measure, protects the metallic matter, but not to such a degree as to prevent entirely the action of the fossil acids, nor even some weak action of the vegetable acids. I shall now describe the preparations made with acids applied to antimony in different states. And first, with the

Sulphuric acid....There are no preparations with this acid in either of our pharmacopœias. A Dr. Klaunig of Breslaw, in a book entitled *Nosocomium Charitatis*, recommends the following : Distil vitriolic acid from antimony several times. By doing this the metallic part is oxydated by the acid, and combined with a part of it : and the sulphur is, at the same time, separated by sublimation. After which, the sulphat of antimony is taken out of the retort, ground to powder, and some alcohol burned on it. It is a medicine, of which two grains work gently, by stool, and vomit, and sweat. And he recommends it strongly for quartans. Wertholfs (in his *Obs. de Febris*) testifies that it is emetic, and purgative, and diaphoretic. Wilson's *antimonium catharticum* is probably of the same nature. Wilson calls it an infallible purge ; and says that he knew three in-

stances of the venereal disorder cured by it. They were probably some cutaneous diseases which he mistook for venereal.

There are no preparations obtained by the action of nitric acid upon crude antimony; unless we choose to consider the *bezoardicum minerale* as such, in some measure; but it is different, as I shall mention presently.

The muriatic acid, assisted with a little nitric acid, or in form of aqua regia, dissolves the metal, and leaves the sulphur. It therefore thus forms a solution of the metal, which is quite the same as if the pure metal had been used. And the corrosive muriat of quicksilver, on account of the abundance of muriatic acid and oxygen it contains, can also be made to act on the metal in sulphuret of antimony, as well as upon the metal in its separate state. The muriat of quicksilver and the sulphuret of antimony being mixed together in powder, and distilled in a retort, a corrosive muriat of antimony arises: and the quicksilver unites with the sulphur, and remains in the retort, in the form of a black sulphuret of quicksilver, which, if the heat be very much increased, sublimes into the neck of the retort, in the form of cinnabar. To this cinnabar the chemists give the name of *cinnabar of antimony*. This was the process most commonly practised for preparing the *antimonial caustic*, or *corrosive muriat of antimony*.

But the London college of physicians, learning probably that the chemists had another method, much cheaper, and which is as good, have adopted it in the last edition of their pharmacopœia. This is, to form the muriat of antimony directly, in the same, or nearly the same way, as was practised for corrosive sublimate. Equal quantities of vitriolic acid and antimonial crocus are mixed with a quantity of common salt equal to their sum, and treated in the distilling apparatus. I refer you to Mr. Russel's own account of the process, given in the first volume of the Transactions of the Royal Society of this place.

It may also be effected by the oxygenated acid, as it is formed by distilling the ordinary muriatic acid from the black oxyd of manganese. But Mr. Russel's process is much better. Scheele's process is not very different.

I observed before, that this antimonial caustic, or muriatic of antimony, is extremely corrosive. On account of its extreme acrimony, chemists studied how to render it milder. The most simple way is, by adding to it plenty of water. The greater part of the acid is thus immediately separated. A small portion remains adhering to the metallic calx; and precipitates with it, in the form of a white powder, called *pulvis Algerothi*, from Victor Algeroth, or Algarotti, formerly a physician at Verona, who called it *pulvis Angelicus*. It is an oxyd very moderately oxydated, and which still retains, as I already observed, a very small portion of the acid combined with it; and on both these accounts, is very soluble in more acid, and also very fusible. It melts most easily into a transparent yellow glass. Mr. Macquer, and others, will have it to be a pure calx, totally free from acid: but in this I am persuaded they are mistaken. Its fusibility is a proof. It dissolves readily in vegetables acids, and in solution of sal ammoniac. It is recommended by Dr. Saunders in this form as a good application to ill-conditioned ulcers; and also as a milder internal medicine.

Bezoardicum minerale may also be considered as a mitigated muriatic of antimony. The preparation of this drug seems to me a process which has been undertaken very much at random, just to see what would result from it.

To four ounces of butter of antimony twelve or sixteen of nitrous acid are added, by two ounces at a time. Violent fumes and ebullition, or effervescence, are immediately produced, which must be carefully avoided, they being extremely acrid or corrosive. The effervescence is less at each subsequent addition. When all is quiet, the whole is distilled to dryness: and the residuum in the retort is the bezoardicum minerale.

The first effervescences are chiefly an oxygenated muriatic acid: and the nitrous acid does not rise till some time after. This is not the usual opinion: and it is even thought that this preparation is nearly the same with diaphoretic antimony, or a perfect white oxyd. It may not be impossible to bring it to this state. But in my own experiments, as well as in the examina-

tion of such specimens as, I was well assured, had been prepared from butter of antimony, I found it to be still a *muriat of antimony*. I believe indeed that the antimonium diaphoreticum is often sold for it, being a much cheaper preparation; and, when made with impure nitre, it may be intrinsically the same. But I have not found that any number of abstractions of pure nitrous acid will free butter of antimony completely from muriatic acid. The mistake, if any, is of little consequence in medicine. But it is perhaps a more difficult matter to explain or account for the deoxygenation of the muriatic acid by means of the nitric, which we know to be the speediest means to oxygenate it. We must consider it, not as a deoxygenation of what part of the acid remains combined with the antimony, but as a *super-oxygenation* of what is expelled from it. The effervescence is violent, and the fumes are uncommonly corrosive. We know that the acid combined in the antimonial muriat is in its oxygenated state. The metal, already saturated with oxygen cannot decompose the nitric acid, and thereby occasion the fumes of aqua regia. It is decomposed by the nascent muriatic acid; and this comes off in a super-oxygenated state. There are two or three other processes in which this rare acid is formed in the same manner.

The only remaining saline preparations are those produced with the vegetable acids. The *antimonium tartarisatum*; (Edin. and Lond.) The *vinum antimonii tartarisatum*; (Edin. and Lond.) and the *vinum antimonii*. (Lond.)

The vegetable acids do not act sensibly upon crude antimony, and but weakly on the pure antimony. To facilitate their action we must take the metal, not only separated from the sulphur but moderately oxydated, or reduced to its most soluble state. Accordingly, the compounds of it with the vegetable acids were formerly ordered in our dispensatories to be prepared either with the washed crocus, or the vitrum antimonii. But the crocus was formerly in most general use for this purpose, (and it is still used at London), until complaints prevailed every where of the weakness, inefficacy, and inequality of the emetic tartar. This was occasioned by frauds in preparing the crocus

used much for horses, &c. The great demand for it encouraged the druggists to attempt cheaper preparations: and instead of employing the *crocus antimonii lotus*, as was directed by the pharmacopœia, which is made by deflagrating equal quantities of nitre and crude antimony, they used only half, or three parts, and even less, of the nitre, the most expensive article. And to succeed the better in bringing the mixture into thin fusion, so as to make an uniform glass, they employed a little alkali. The result of all this is a preparation nearly the same with the *regulus medicinalis*; a drug almost inactive, and insoluble. If the weakness of this preparation were all its imperfection, it could easily be remedied by increasing the dose. But, by thus stinting the nitre, it is almost impossible to make an uniform mass; and different portions of the same lump will often be in different states. This spurious *crocus* may be easily distinguished from the true by its colour. In the mass the spurious is opaque, and almost black: and when reduced to fine powder, it is of a dirty purple colour. The genuine is liver-coloured in the mass, and a deep yellow when finely powdered.

Now the state of the *crocus* is of most consequence for the preparation of emetic tartar; for a large quantity of the nitre is necessary for destroying the sulphur, and then bringing the metal into that state of moderate oxydation that renders it most soluble in the weak acids. Less nitre will leave some sulphur, which sheathes the metal; and the pure *regulus* has little solubility in the vegetable acids, and requires a little previous oxydation.

In consequence of these frauds in preparing the *crocus*, the emetic tartars and wines, as prepared by different apothecaries, were widely different in strength, and often totally disappointed the practitioner.

Different chemists have exerted themselves to remedy this inconvenience in a medicine of so much activity and importance,...indeed the most valuable of the antimonial medicines; and in consequence of their experiments, and of what has been published on this subject, the *tartrite of antimony*, or *antimonium tartarisatum*, is now always made, I believe, sufficiently strong.

One of the best processes they recommended, and which was lately the process of the Edinburg Pharmacopœia, was to use the vitrum antimonii, which is preferable to crocus, because we have no experience yet of any mistakes or frauds committed with regard to it, and we can always know if it be good. We are there directed to beat it to very fine powder, and mix it with an equal weight of the crystals of tartar, also powdered. In the next place, for every ounce of the mixture, or half ounce of tartar, take one pound of pure water, (distilled water is the best,) and set it in a furnace to boil. As soon as it boils, throw in the mixture of tartar and vitrum by degrees, until all is in; and continue to boil gently for several hours. The number of hours necessary cannot be specified with precision. It depends upon the degree of pulverization of the vitrum. If it be a very fine and almost impalpable powder, about four hours, or even less; if not so fine, twelve hours. It is more necessary to attend to this, when the vitrum is employed, than when we employ the crocus. The first, being powdered mechanically, can never be so impalpably levigated as the crocus, which falls a soft powder, completely divided by the separation of the saline matter. Beaumé, in examining the preparations of eminent apothecaries, found differences in the quantity of metal obtainable from an ounce of the tartarized antimony, which were surprisingly great. In some he found 150, and in others scarcely 40 grains. Vinum emeticum may also differ in consequence of a difference in the acidity of the wine.

I need scarcely insist on the necessity of much water and a boiling heat. We know that water dissolves only one-twenty-fourth of its weight of tartar with a boiling heat; and that it lets go a great portion of this by a moderate diminution of its heat.

Mr. Macquer would prescribe the mercurius vitæ in preference to the crocus or glass, as more to be depended on for perfect uniformity. But I do not see reason to doubt of the goodness of these preparations; and prescribing so costly a thing as mercurius vitæ would only occasion more substitutions or adulterations.

Beaumé has further given a caution with regard to the vessel in which the mixture is boiled. He says it must neither be iron nor copper. He finds that these vessels decompose the emetic tartar in some measure. The vessel must be glass, or silver, or earthen ware not glazed with lead. But M. de la Caille assures us that iron may be used.

When the operation is conducted in this manner, the tartar is saturated with the antimonial calx, part of which remains undissolved. And the liquor being filtrated affords, by evaporation, fair crystals, pyramids of three sides,.... transparent while wet, but becoming white and opaque in the air. And these crystals are the saturated tartrate; and are powerfully emetic. The dose is from one grain, or one-half, to two, or three at the utmost, for an emetic. This may seem an inconvenience: but it is easily remedied by mixing ten grains, for instance, with three or four times as much sugar; and thus we will have a powder which it will be easy to weigh out in moderate doses: or a more common way is to dilute it in water,....three or four grains, for example, in six ounces; and a spoonful is taken every half hour until it operate.

But beside the vitrum antimonii, any other preparation in which the metal is freed from the sulphur, and very moderately oxydated, may be employed to saturate the tartar, and produce a medicine equally powerful and certain.

To complete this article, Dr. Saunders added a simple and useful method of examining emetic tartar, so as to judge if it be properly prepared, and as strong as possible, or what degree of strength it possesses. On examining the solubility of different tartars, he found, by experiments, that they are more soluble in proportion as they are more completely saturated with antimony: and that the difference among tartars, in this respect, is so considerable, that it is easy to distinguish them. Thus, one ounce of water, at a middling temperature, dissolved,

Of the saturated tartar	52 grains.
Apothecaries' hall	38
A London chemist's	32
Edinburgh shops	less.

I only wish he had specified the degree of heat more particularly.

The next set of preparations we have to mention are the *reguli*, and preparations from them.

The process by which antimony is obtained in the largest quantity and purest, is similar to that followed in extracting other metals from sulphurous ores, viz. evaporation of the sulphur by ustulation, and reduction of the calx. But other processes have been commonly followed. These have in general been two: the process for simple regulus of antimony, and that for martial regulus of antimony.

For the simple metal, or what is called simply *regulus of antimony*, the crude antimony is melted with about half its weight of black flux, or rather the ingredients for producing black flux, viz. nitre and tartar, which occasions part of the regulus to separate: the hepar sulphuris formed by the alkali and sulphur, having rather more attraction for the charcoal of the black flux than for the metal. But this superiority of attraction is not so great as to occasion a complete separation of the antimony. Part only separates. The rest remains dissolved in the saline sulphurous scoria, and forms with it a hepar antimonii, and is employed as such in the London Pharmacopœia.

The other process which I said is also often followed, is that for *regulus antimonii martialis*. Crude antimony and iron filings, or small nails, in equal parts, are mixed and melted with a violent heat, and commonly with the addition of a small quantity of nitre or fixed alkali. In this operation, the sulphur shews a stronger attraction for the iron than for the antimony; and forms with the iron a hard sulphurous compound. The antimony sinks separately in large quantity, but not so pure as by the former process. It dissolves some of the iron. It is purified by crude antimony, and two or three meltings with a little nitre. The sulphur of the crude antimony forms a scoria with the iron, and floats above: and thus the regulus is freed from the iron. Melting again with nitre destroys the sulphur brought in by the crude antimony, and not carried up by the iron. Thus it may be made as pure as the other. Many other metals may also be used;

all, except gold, zinc, and platinum, having a stronger attraction for sulphur than antimony has.*

In whatever manner the antimony is separated from sulphur, if it be made very pure, and cast into a conical vessel, it exhibits a star. *Regulus antimonii stellatus*,...*regulus stellatus*. Many mysteries have been supposed to be indicated by the figure which the surface of this metal assumes in cooling; it having generally a stellated or radiated figure. This is owing to its mode of crystallization, combined with the progress of cooling, which proceeds from the sides of the vessel to the centre. It is needless to take up your time with proving the folly of these fancies.

Preparations from the Regulus....Cerussa antimonii; stomachicum Poterii; cardiacum Poterii; antihecticum Poterii; tinctures of antimony.

*Uses of Antimony....*It affords, in many of its preparations, medicines of great efficacy to remove many diseases of the human body, as well as of other animals.

In the arts, it is used for refining gold: and the regulus is mixed with tin and lead to harden them, for the composition of pewter. But I apprehend that the greatest quantities are employed to mix with these metals for letter founding. In this composition, great hardness, and great fusibility, are important properties. It is also peculiarly fortunate, that the latent heat necessary for the fluidity of this composition is very moderate; so that a man can work without intermission, when the letters are small. The mould loses so much heat while opening to shake out the letter, and shutting again, that the next letter makes no accumulation of heat. Were it otherwise, the mould must be cooled after a few letters, and the expedition of the work greatly diminished.

* Lehman relates a very singular experiment made with antimony and arsenic, which being distilled together, with a violent heat, yield a sulphurous sublimate, which does not defflagrate with nitre: and he says that a regulus of antimony remained in the retort. I found this residuum not distinguishable from a regulus by its chemical properties, but very distinguishable from it by a beautiful changeable colour upon the facets of the metal when broken. I attributed this to a film of arsenic, which, being transparent, should exhibit such colours. But no trial that I could put it to supported my conjecture. The sublimate did not defflagrate, but burnt slowly with a dull heat....EDITOR.

GENUS VI.....ZINC, OR SPELTER.

ANOTHER brittle metal, or semimetal, bears some resemblance to the last. Like it, it shews a plated texture when broken. But it is easily distinguished. 1st. It is not so brittle; but can be compressed by the strokes of a hammer; and even bears some degree of extension under the hammer. It bears extension by rollers very well; and can thus be drawn into very thin plates, if carefully annealed between the operations. It also bears drawing in the wire-plate. It has therefore more cohesion, and is broken to pieces with more difficulty. The plates are not so broad: and its colour inclines to bluish, when compared with the other two. It is the most expansible of all the metals by heat. It melts before it begins to grow red hot; and flows quite thin at 680. When melted and poured into a vessel, it may be reduced to a pretty fine powder by simple agitation. Its specific gravity is nearly 7,2. It has some singular properties relative to its solid form. This imperfect ductility is accompanied by a singular kind of toughness, which makes it extremely difficult to work it in the ordinary way, by filing it. It sticks in the files; and soon renders them useless. Lead, though a much softer metal, has not this quality. Pure copper has a little of it. It sticks in like manner to the edges of the cutting tools, with which it is scraped or turned in the lathe; and, what is still more singular, when mixed with copper which has the same quality, it forms a metal which the workmen find to work more pleasantly than any other metal. Moreover, although annealing it, after every passage through the flatting mill, enables it to extend much more than it would otherwise do, yet if it be hammered in its hot state, it crumbles to pieces with the greatest ease.

If the heat be further increased to a vivid red or white heat, in close vessels of proper form, such as an earthen retort or receiver, the whole arises in vapour, which, in close vessels, may be condensed again without further change. But when the same

heat is applied in the open air, it suddenly takes fire like an inflammable body, and burns rapidly, with a bright and dazzling flame: and the metal is quickly changed into a calx. This is very white, and soft, and rarefied, in comparison with other metallic calces. The greater part of this calx is accumulated in the vessel, just over the burning zinc, and soon impedes the further action of the air on the remaining zinc. But some part of it rises up into the air, and floats or flies about in it like cobwebs. In this state it was called *pompholix*, and *philosophic wool*, also *nihil album*. This, therefore, is the most expeditious method of calcining zinc. The process described in the Edinburgh Pharmacopœia is this: "Place a large or deep crucible, or other deep earthen vessel, in a melting furnace, inclined a little towards the door. When heated to the proper degree, let the zinc be thrown into it in small pieces, waiting till the first is entirely burnt, before the second is thrown in. Thus the oxyd of the zinc is accumulated in the crucible; and being light and bulky, it must be stirred now and then with an iron rod, that the air may be admitted to the burning metal. And when a quantity of it is accumulated, it must be taken out with an iron spoon before any more of the zinc is thrown in."

The late Professor Gaubius of Leyden, who recommended this oxyd to physicians as an useful remedy for convulsive disorders, described a different way of preparing it, but not so good.

From these phenomena, it is evident that this metal is one of the most calcinable of any, when it is exposed to a violent heat. And it is reasonable to conclude, from the great brilliancy of its flame, and the great heat which its inflammation produces, that in its calcination it attaches to itself a very great quantity of oxygen. But it has not a disposition to attract oxygen easily from the atmosphere, and to calcine by means of humidity, without the assistance of heat, in which it differs from iron and most other metals.*

* It is not altogether inactive in this respect. Its polish is very easily tarnished by exposing it to very damp air: and if wetted, and kept in that state an hour or two, its polish is entirely taken away, and it becomes of a dull leaden colour. When viewed in this state with a microscope, we see

The oxyd of zinc is so unfusible, because it is probably more highly calcined than the fusible oxyds of some other metals. It is, however, in some degree fusible in a very violent heat, and forms a fine yellow glass.

The reduction of this oxyd was long a difficult problem. It was found so difficult, that many supposed it impossible. But this proceeded from the improper manner of attempting it. They tried it in the manner usually practised with other metals, by mixing the oxyd in a crucible with black flux, or with charcoal and salts. In this way the heat which was necessary for the reduction, was sufficient for totally evaporating the metal as soon as it was formed. It was therefore all lost.

Mr. Margraaf, attending to this, first contrived to accomplish the reduction. He mixed the oxyd with one-eighth of its weight of powdered charcoal, or lamp black; introduced the mixture into a small earthen retort luted to a receiver; and urged it with an intense white heat. He thus got zinc again in the form of a metallic sublimate, or mass, attached to the neck of the retort: and he found it rather more malleable than ordinary zinc.

The same expedient occurred to Neuman: but he tried too small a quantity, (two drachms) so that the air inclosed was sufficient to burn the zinc again. And he got nothing but half burnt flowers in the neck of the retort, which shewed, unquestionably, that they had been once reduced, otherwise the calx would never have been sublimed.

Zinc is easily dissolved by all the acids; and is united with them by a very strong attraction. The acids are therefore more neutralized by it than by most other metals: and the compounds do not easily suffer any separation of the acid from the metal by large dilution with water.

The sulphuric acid even requires to be diluted considerably with water, to make it dissolve the zinc well, just as in dis-
it evidently corroded. But I have not observed this to increase by length of time. This is surely an oxydation, or rust. It seems completely to cover the surface, rendering it neutral or saturated; and this defends the interior parts. But if the metal be made nearly red hot, and water be sprinkled on it with a brush, it then acts powerfully on the water, decomposes it, and produces much hydrogenous gas. Zinc is oxydated in this way, just as iron is.....EDITOR.

solving iron. And further, the zinc, while dissolved by this acid, decomposes a part of the water, as iron does: and a great quantity of inflammable air is, in consequence, produced during the brisk effervescence with which this dissolution is performed. One ounce of zinc produces 356 ounce measures with one ounce of sulphuric acid. One ounce of iron gives 412 of air, with 2 ounces of the acid. The metal is therefore oxydated as well as dissolved, but receives all the oxygen from the water. The compound of oxydated zinc and sulphuric acid thus formed is easily crystallized; and gives crystals that are not deliquescent. They are an article of the materia medica; and were named formerly *white vitriol*; in the new language of chemistry, *sulphat of zinc*.

The nitric acid, in the diluted state of aquafortis, dissolves this metal with the greatest violence and rapidity; and becomes excessively hot. In the violent effervescence which attends this dissolution, the acid suffers a great and violent abstraction of its oxygen, and all the changes which are necessary concomitants of such abstraction. Part of it is therefore changed into red vapours; a great part into nitrous gas; another part into the less oxydated nitrous gas, which I lately described; and lastly a part into pure azote.

By some variations in the manner of dissolving the metal, we can modify these changes of the acid. If, for example, the aquafortis be largely diluted with water before it be applied to the metal, the gas produced is almost totally the less oxydated nitrous gas, or dephlogisticated nitrous gas of Dr. Priestley.

The muriatic acid, in its common state, also dissolves zinc easily, with effervescence and production of a great quantity of inflammable air. But when applied in its oxygenated state, there is no inflammable air produced. The reason is obvious. The zinc is supplied with oxygen, which was very loosely combined with the acid. This muriat of zinc does not give crystals easily. It is a deliquescent compound. The solution of it, mixed with glue, or employed to dissolve it, forms a compound which does not become dry in the air, but has the inviscating quality of birdlime. This birdlime would probably be the best for catching birds and insects for the natural historian; as it

could easily be washed off from the feathers of birds, or limbs of insects, by water.

The vegetable acids act also on zinc without difficulty and some inflammable air is produced during their action. The oxyd of zinc also dissolves in all the acids, but without effervescence. A saturated solution in the acetous acid is a liquor very like olive oil.

The alkalis act on zinc as upon some other metals. Applied to it in its metallic state, they corrode it in some measure. Applied to it in the state of oxyd precipitated from acids, they in some cases dissolve it. Volatile alkali is thought to act on it in a peculiar manner. When powdered zinc is put into a solution of the caustic volatile alkali, it yields, after a long time, inflammable air. This, however, seems rather to come from the water than from the alkali. Did it come from the alkali, we should also obtain azotic gas, which I have never been able to discover by this treatment.

Such of the compound salts as act on other metals, act more readily upon zinc, which, in consequence of its inflammable nature, produces remarkable effects on them, similar to those produced by the inflammable bodies. Thus, melted with sulphat of potash or of soda, it changes them into alkaline sulphuret, and is changed itself into an oxyd: and with the salt of urine, or phosphoric acid, it yields phosphorus. It also decomposes sal ammoniac, by grinding them together, as appears by Margraaf's experiments, which I mentioned when delivering the theory of lime. This is unquestionably owing to its very strong attraction for acids, which is such, that alkalis decompose the nitrate of zinc with difficulty. To the same cause we may ascribe the decomposition of alum by boiling it with zinc. If the sal ammoniac and zinc be treated in the way of distillation, we obtain first an incondensable suffocating alkali,...then a volatile muriatic acid, in thick white fumes,...in an open fire, white flowers succeed; and at length, a reddish and a black butter.

Nitre deflagrates violently with zinc. But it must be heated so hot that it is not easy to distinguish its deflagration with the nitre from the inflammation to which it is so much disposed of

itself. Its flowers do not sensibly deflagrate; yet they alkalize double their weight of nitre. The fixed alkali and calx form together a mass externally greenish, internally purple. Infused in water, the alkali dissolves, and with it a part of the calx, tinging the water purple.*

Zinc does not unite with sulphur, nor hepar sulphuris, nor with crude antimony; and is therefore purified by the action of sulphur from admixtures of lead, which it frequently contains. Alkaline and calcareous sulphurets, however readily unite with the calx, and dissolve it, forming a substance resembling its ores.

None of the earths have been observed to have any remarkable effect on zinc or its calx.

It unites with all the metals except bismuth and nickel. It is indeed difficult to combine it with iron; because the great heat that is necessary dissipates the volatile metal, and it carries off some iron with it. It has somewhat of this effect on all the more calcinable metals. Most of these mixtures boil and deflagrate more than zinc alone, and globules of the metal are frequently scattered about. Hence it is called *metallic nitre*. Copper is but little affected this way: and the *cadmia fornacum* of the brass-founderies rarely contains any copper. When they are melted separately, and then mixed, there is frequently a violent detonation, and much of the metal is thrown about. When lead is added to melted zinc, the mixture takes fire, and the zinc burns away. They mix quickly, when the zinc is added to melted lead. Arsenic makes it black and friable.

United with mercury in the form of amalgam, it is the most powerful exciter of an electric globe. The best proportion is four parts of mercury to one of zinc.

Mixed with tin, in a small portion, it greatly increases its hardness, and improves its colour, making it like silver. But this mixture is more apt to be corroded by acids. It is used, however, in the manufacture of pewter.

* With respect to the other neutral salts, the only remarkable effect that I know, is the formation of a butyraceous sublimate of zinc, like the muriat of antimony, by distilling common salt and the sulphat of zinc, or by subliming the solution of zinc in the oxygenated muriatic acid... EDITOR.

Mixed with lead in the proportion of one to twelve, or even less, it improves its tenacity in a most surprising manner, making it four or five times stronger. It would therefore be a great improvement on water pipes.

The most useful mixtures of zinc are those with copper, in various proportions. It communicates a yellow colour, notwithstanding its own whiteness: and it removes the disagreeable toughness which makes copper so difficult to work with the file and in the lathe, while it very little impairs its tenacity and ductility. In a very large proportion to the copper, it makes the *hard*, or *spelter-solder*, used for copper, brass, and iron. In a smaller proportion, it makes brass: and in other proportions it makes more or less perfect imitations of gold. Such are *pinchbeck*,.. *princes metal*,....*similar*,*Bath metal*,....*tutenag*, &c. Homberg, Geoffroy, Hellot, and Lewis, have made many experiments and useful observations on these mixtures: and to their writings I refer you for farther information on this head. Observing, in general, that all these mixtures lose some of the zinc by evaporation in great heats: and that long continuance of it will expel the whole. This is owing both to the volatility and to the inflammability of the zinc. You will always observe an uncommon brightness on the surface of the melted metal, greater than that of the surrounding fuel. This is just a low flame, not one-tenth of an inch high.

It remains only to mention the operations by which it is extracted from its ores.

For a long time, all the zinc used in Europe was imported from China, except a small quantity which was obtained in the Hartz forest in Germany, from an ore which yielded lead, and copper, and silver, and a little gold at the same time. We have not been informed how the Chinese zinc is obtained. The process by which the German was procured was a little uncommon.

In the side of the furnace, (which is a reverberatory) opposite to the bellows, the wall is double, consisting of two thin fire stones, with a hollow between. On a level with the usual surface of the melted metal, there is a chink opening into this cavity. The zinc evaporates as fast as it is formed: and the vapour is driven into this hollow through the chink

by the blast of the bellows. The side of the cavity, which is in contact with the air of the hut, is cool in comparison with the rest, the stone being thin and being often sprinkled with water. Here, therefore, the sublimed metal attaches itself, while the flowers, which are unavoidably formed by the calcination of part of this metallic vapour, rise farther up, and get into the long funnel, where they collect, and are got out from time to time by the name of *cadmia fornacum*, *Tutia*, *diaphryges*.

This very singular process was the contrivance of a common smelter, who had observed this strange metal collecting in the retired corners of the furnace, at Rammelsberg. It is certainly ingenious, and shews a sagacious and intelligent mind. Such have been most of the processes in metallurgy: and it is by a collection of these casual arts that our science has arisen. The quantity thus procured was but very small: and no other method was known or attempted in Europe for producing this metal, although its ores, which are very plentiful, appear to have been sufficiently known as such from their effect in making brass.

In the greater part of these ores, the zinc is in the state of a calx; in consequence of which, they appear more like stones than metallic minerals; and were actually considered by many as a particular species of stone or earthy matter, and called *lapis calaminaris*. The original name, however, by which it was known to the ancients, and mentioned by Pliny, was that of *cadmia*.

Sometimes it is in a less calcined state, which gives it more or less metallic opacity and lustre: and in some cases there is sulphur in its composition, which produces the same effect. It is then called *black Jack*, by the English miners; by the Germans, *blende*; and by natural historians, *pseudogulana*,...*i. e.* mock-lead ore.

This ore is somewhat curious. It is transparent when pure; and in a very strong light, although seemingly opaque, it transmits a very deep brown light. It breaks also with a glassy fracture. Notwithstanding these marks of being homogeneous, a bit of it, slowly dissolved in weak aquafortis, leaves a spongy mass, which retains the original shape com-

pletely: and this weighs about one-fifth or one-sixth of the blende. It is pure sulphur, not chemically combined.

• These several varieties of it have been long employed for making of brass. The process consists first of roasting; then cementation with charcoal and copper. The copper fixes the zinc, and acquires the yellow colour.

This was the only use made of the ores of zinc in Europe: and the manner in which they produced their effect was not thoroughly understood, until Mr. Margraaf extracted zinc from them, without the assistance of any other metal. But now, in consequence of his discovery, manufactories of zinc have been established in England, and elsewhere.

The English process is what the chemists call *destillatio per descensum*. The ore, mixed with charcoal, is put into conical pots, having in the bottom an iron pipe, which passes through a hole in the hearth of the furnace, and reaches to the mouth of a rude receiver containing water. Fuel being kindled around the pots, (whose mouths are stopped with clay) and care being taken that it shall not be so hot as to melt their contents, the metallic vapours are expelled downwards, and condensed in the receivers.

But lapis calaminaris is still much more used for making brass, the process for which is the cheapest way of extracting the zinc, while by the same fire it is also mixed with the copper. The ore being cleared from sulphur, and other impurities, by roasting, is ground and mixed with charcoal. The mixture is put into pots, and stratified with plates of copper. A proper heat being given, the ore is metallized, and the metallic vapour is immediately seized on by the copper,.... renders it more fusible, and melts down with it, and lodges in the bottom of the pot, where it is defended from the air by the vitrified slag floating above it. When the proportion is properly observed, the copper gains an addition of one-third of its weight, in becoming brass.

Although copper fixes zinc to a certain degree, it does not entirely prevent its evaporation and calcination in strong heats. Hence when brass is melted, if it be exposed to air, it is liable to lose part of the zinc, and by repeated fusions, the whole. Hence *cadmia fornacum*,....*pompholix*,....*diaphryges*,....*nihil album*,....*tutia*, &c. which are different names for

the condensed vapours which escape from the furnaces in these processes for brass.

Uses of Zinc.....It is chiefly useful for metallic compounds,brass,....pinchbeck,....pewter,....for tinning,....and for solders: and it is an useful article of the materia medica.

Until lately, zinc was hardly ever used internally: except sometimes the white vitriol was used as a vomit of quick operation. It was chiefly confined to external use. It possesses useful powers as an astringent and repellent; and is used particularly in inflammations of the eyes. Its preparations are,....*Lapis calaminaris preparatus*; Edin. and Lond.*Tutia preparata*; Ed. and Lond....*Calx zinci*, vulgò, *flores zinci*; Ed....*Zincum calcinatum*; Lond....*Vitriolum album*; Ed. made of zinc and sulphuric acid....*Zincum vitriolatum purificatum*; Lond....*Aqua vitriolacea*; Ed....*Ceratum è lapide calaminari*; Ed....*Unguentum è tutia*; Ed. and Lond... *Unguentum è calce zinci*; Ed.

But certainly, it might be easy to substitute preparations of this metal, instead of some of these, which could be much more depended on. For lapis calaminaris is extremely different, (*Vide Essays on different kinds of it, by Margraaf,*) and may accidentally contain arsenic and other minerals.

With respect to tutia, see the experiments of Neuman, which shew it plainly to be artificial. And it is seldom sufficiently levigated for ointments.

Both of these might be excellently superseded by a pure calx of zinc, or pompholix, which is extremely fine; and the vitriolum album by an artificial sulphat of zinc.

When the chemical state of the preparations is once such as may be depended on, they are medicines of very uniform operation, and of considerable powers. The sulphat in the dose, a drachm or a drachm and a half, is a quick emetic, with little distress or sickness. The calx in much smaller doses, not exceeding five grains, produces sickness and vomiting. We are but little informed hitherto as to the internal use of the preparations of zinc. But it has been long known as a powerful astringent, emollient, and cooling application, when we desire to remove the remains of a tedious inflammation, and restore strength to the vessels.

The sulphat and nitrate, in the quantity of two grains to an ounce of water, answer very well in such cases.

GENUS VII....BISMUTH, OR TINGLASS.

BISMUTH has a near resemblance to antimony in external appearance. It is nearly as brittle, and exhibits the same texture when broken. But it is much heavier; its specific gravity being 9,823: and the colour of it inclines a little to red. It is also more fusible, and less volatile than antimony. It melts sooner than lead; and flows the thinnest of all the metals. It also expands in congealing, and therefore takes the finest impressions of its mould.

This metallic substance is easily calcined to a moderate degree, forming in its oxydated state a very thin yellowish glass, one-eighth heavier than the metal. But it is difficult to calcine it further; at least the oxyd of it is always fusible in a moderate red heat; by which quality, and some others, it resembles the oxyds of lead. It may be procured, either by keeping the bismuth melted, and stirring it constantly, to expose the different parts of it to the air, or more quickly, by way of scorification in a more violent heat, which may calcine it faster, and melt the calx as fast as it is formed; so that it may constantly run off from the surface of the melted metal, and leave it exposed. The metal smokes constantly, while any of it remains uncalcined: and a faint blue flame may be observed on its surface.

It is easily reduced again, by melting it with addition of charcoal, or of the black flux.

When we try it in mixture with salts, we find that the sulphuric acid acts only when applied strong, and assisted with heat. The metal is then corroded and oxydated, by attracting oxygen from the acid: but we do not get a soluble compound.

A soluble compound of this metal is best and most easily obtained by the action of the nitric acid, which dissolves it with a strong effervescence, and the production of great heat,

red vapours, and nitrous gas, in consequence of the abstraction of oxygen from a part of the acid by the dissolving metal. The solution, when completed, is almost colourless: and the compound it contains is liable to suffer an imperfect separation of the acid from the metal, when we dilute it largely with water.

This precipitate has been supposed by some authors to be the pearl white, said to be employed as a cosmetic: and it is said also that the transpiration by the skin blackens the oxyd, as if by an imperfect reduction, and thus destroys the skin. But I believe that this is a mistake, having examined many specimens of pearl white, which I found to be precipitates from a nitrate by a solution of common salt, or of tartar. Water alone makes but a very imperfect separation, and leaves so much acid adhering to the metal, as unfits it for any such purpose.

In consequence of this mutability of colour by the steams of inflammable substances, the solutions of bismuth, like those of some other metals, form what are called *sympathetic inks*; that is, inks which are invisible, till something has been done to the paper. When we write with the solution of the nitrate of bismuth, the exhalation from hepar sulphuris, or putrescent animal substances, soon make the writing legible. All bad smells have this effect.

You will find in Neuman (*p.* 107, 108.) a number of experiments upon the precipitation of bismuth from aquafortis, by a variety of different additions, which you may consult, if you have occasion to attend to this particular subject.

The same author also describes a process for combining bismuth with the muriatic acid, by means of muriat of mercury, and the consequences of dissolving it with vegetable acids and alkalis, and of uniting it with sulphur, with which it forms a mass very like crude antimony. To him, therefore, I refer you for these particulars, which are not so important as to require our time. Mr. Pott of Berlin also may be consulted, who wrote a dissertation upon this metal.

The compounds of bismuth are remarkably fusible, so that it may be employed in the composition of solders for lead or tin. The fusible metal, called *Newton's metal*, has bismuth

for its principal ingredient. The best proportions for the fusible metal are, eight parts of bismuth, five of lead, and three of tin. When thus mixed, it will become fluid in a temperature something below that of boiling water. It is from the same cause, probably, that when dissolved in mercury, it disposes the mercury to form more fluid amalgams with other metals, particularly with lead, than ordinary. And hence it has been proposed to be added to mercury, the more readily to dissolve lead balls lodged deep in a wound. Mr. Lewis says (*Notes on Neuman*, p. 93.) that mercury united into a fluid amalgam with one-fourth, one-eighth, or one-twelfth of its weight of bismuth, dissolves masses of lead in a gentle warmth, without the necessity of agitation. Whether this would answer the purpose, I cannot positively say; because the bismuth, or part of it, separates in the form of powder while the lead dissolves, which might possibly prove inconvenient. An abuse of this quality of bismuth has been practised in adulterating mercury.

The principal uses of bismuth are, to mix with tin for proper hardness in the composition of pewter for solders for lead and tin. It is sometimes used also in the composition of metal for printers' types; and when used, seems to be intended for greater tenuity of fusion, and sharp impression. The proper degree of hardness is always procured by the cheaper regulus of antimony. With lead one part, tin one, bismuth two, and mercury ten parts, it composes a kind of fluid amalgam, which being moved backwards and forwards in a clean glass vessel, leaves a train behind it, adheres to the glass, and foils or silvers it. It is therefore used for foiling the inside of glass globes. (*Vide Boyle's Treatise on the Usefulness of Exper. Phil.*; and for other uses, *vide Neuman*, p. 112.) But it has never been introduced into the materia medica, nor is there any reason yet for introducing it.

Its ore is most plentiful in Saxony, near Schneeberg. There is some too in Bohemia, and in Duaphiné, and some in England. Sometimes the bismuth is found pure; seldom or never a vein of it pure, but intermixed with other ores; especially arsenical, and particularly the ore called *cobalt*. The bismuth is easily separated from the ore by eliquation.

It separates in its metallic form ; and runs along the inclined hearth into a channel, by which it is conveyed to a receptacle, where it is defended from the further action of heat. Mr. Macquer gives a long account of a very curious tincture, or solution, obtained from ores of this kind. But as the bismuth has no part in its production, I shall consider it afterwards in its proper place.

GENUS VIII.....COBALT.

THIS name has been long appropriated to certain minerals or ores, which when duly prepared, and melted with glass or enamels, give them a deep and rich blue colour. In their natural state, these ores have commonly the metallic opacity and lustre, and a colour resembling that of iron, although it is various, in consequence of their being more or less compounded with other minerals.

Those parts of them which are long exposed to the air are liable to decay, and contract a sort of rust which has a pale purplish red or pink colour, like that of peach blossoms. It is named *cobalt bloom*.

All the varieties of cobalt generally contain a large quantity of arsenic, the greater part of which is easily separated from them by ustulation: after which, the remaining metallic matter is an oxyd of a dark colour, like soot, or sometimes it has a violet hue. It still retains arsenic, which appears to have been changed by the ustulating process into its acid state, and in that state remains strongly combined with the oxyd of cobalt.

The dark coloured oxyd, obtained by ustulating the ores of cobalt, is named *'zaffre*; * and, when added to glass, or the materials for making glass, gives it the blue, or deep, violet colour, in proportion to the quantity used. But it was employed for this purpose a long time before we knew that it could be reduced to a metallic state. Dr. Brandt, of the Swedish academy, first shewed that it may be procured by

* This zaffre, however, which we procure in the shops, contains but a fourth or fifth part of this oxyd; and the rest is powdered flint.

the help of the common inflammable fluxes : and he called it *regulus of cobalt*. From the experiments he made upon it, as well as the properties of its calx which were known before, there is no doubt but that it is a metallic substance,....a semi-metal of a peculiar kind. The following are its most remarkable qualities.

Its colour approaches to that of iron or antimony. It breaks with a granulated surface, like steel. Its specific gravity is 7,7. It requires a pretty strong red heat to its fusion, and can be calcined without difficulty. But its calcination goes on slowly, like that of copper, and without the appearances of inflammation. The calx produced from it is always of a blackish colour, and is not easily melted by itself. But if it be added to glass, it melts with it, and colours it to different shades of blue,....from the lightest to a deep blue, which appears black.

Of the acids aquafortis dissolves it the most readily, and with effervescence. The sulphuric acid will not act upon it, except when applied strong, and with the assistance of heat. A very diluted acid, however, will readily dissolve the oxyd obtained by precipitation from any acid, by alkali or lime. The muriatic acid acts best upon the calx, or when it is assisted with a little of the nitric acid. The solution has a faint rose colour, which becomes green when heated.

All the saline compounds thus produced are soluble in water, and capable of being largely diluted without separation of the acid : and the solutions are all of a rose colour, or reddish.

The muriatic solution, as also the saline compound which it contains, is remarkable for changing its colour when gently heated, and resuming its former colour when the heat leaves it. Air deprived of its natural humidity by quicklime, or by sulphuric acid, produces the same effect ; and breathing damp on it effaces the green, though hot.

This solution is the *sympathetic ink* of Mr. Hellot ; and is the most curious of all the preparations which go by that name. The process for it is described by Macquer. Hellot described it as produced from ore of bismuth : but this was a mistake, as I mentioned when describing the properties

of that metal. The calx, or zaffre, is dissolved in aqua regia, (which keeps it much better suspended than aquafortis) and the solution, when cold, has a pale rose colour, and becomes green when hot. Writings with this solution are invisible (when recently done) in the cold. But when held before a fire, they acquire a beautiful leek green colour. This disappears again when cold, and may be renewed by heat. And this may be repeated as often as we please, taking care that we do not make the paper too hot. This will render the colour permanent. Frequent repetition has somewhat of this effect: and in this respect, a solution of the calx in muriatic acid is preferable to that in aqua regia. If a drawing of a plant of abundant foliage be washed with a full straw colour, which is not very unlike the withered leaf of some plants, the solution of cobalt being laid over it, raises it to a very beautiful lively green: and is a pretty fancy for a fire-screen. There is another preparation of a similar kind, made by boiling oxyd of cobalt in sixteen times its weight of distilled vinegar, till the liquor is reduced to one-fourth. It is filtered, and again reduced by evaporation to one-half. Muriat of soda is now added to it,...and the muriatic acid takes the oxyd from the acetous. This solution is invisible, like the other, when cold; but when heated, shews a fine blue, which disappears on cooling.*

In trying to mix cobalt with other metals, it has been found incapable of uniting with mercury and lead, except in small quantity, or with silver, according to Bergman. It mingles with all the rest; and makes the most malleable metals quite brittle. But it was thought rather to increase the toughness of iron.

It is precipitated from acids by zinc, but not by iron.

* The action of the neutral salts has not been much attended to. It is somewhat remarkable that it scarcely detonates with nitre,...less than even copper. Yet in its oxydation, it seems to combine with more oxygen than any other metal. The oxyd produced from 100 grains weighs 140 (Fourcroy.) Nitre calcines or oxydates it. What becomes of the caloric of the oxygen? The difficulty to reconcile this with the general doctrine is great, but not peculiar to this metal: for the deflagration of the metals with nitre is by no means in the proportion that we should expect from their increase of weight by calcination..

When borax, which has been tinged with cobalt, is boiled in water, the water dissolves the borax, and leaves a firm gelatinous matter, which becomes friable by drying, and of a transparent rose colour, like cobalt bloom.

The only use that I know to be made of cobalt, is to tinge glass and enamels. The calx or zaffre, being mixed with a certain proportion of flint or glass, is melted, and forms a glass of a rich purplish blue. This is ground to a coarse powder, and sold by the name of *smalt*,...in which state it is used by the sign-painters. Smalt is ground in mills to a very fine powder, which is sorted, by its precipitation in water, into parcels of different fineness, and sold by the name of *powder blue*. The same compound, ground to the utmost degree of fineness, is used in painting all the blue that we see on porcelain, Delft ware, and all other imitations of porcelain. Some of it has a richness of colour surpassing all other works of the pencil. This is particularly remarkable in the Saxon porcelain. The painters in enamel complain that it is so fusible, that the heat necessary for raising their other colours makes the blue spread just as ink does on bibulous paper.

GENUS IX....NICCOLUM.

THE name now given to this metal is derived from the name which was first given to the ore of it by the German miners, at Freyberg in Saxony, where it is most abundant.

As the colour of this ore resembles in some degree the colour of copper, they expected at first to obtain copper from it. But not succeeding in their attempts to obtain copper from it by any process, they gave it the name of *cupfer nickel*,... the literal translation of which into English is *Niccol's copper*.

A laborious investigation of the component parts of this ore by several of the modern chemists, especially Cronstedt and Bergmann, has shewn that it contains a peculiar metal, to which the name *niccolum* is now appropriated, but which is intimately and strongly combined in the ore with several

others, and with sulphur. Cronstedt was the first who made the discovery. The other metals present in this ore are iron, arsenic, and generally some cobalt. And all these ingredients cohere so strongly together, that an attempt to separate them, or to obtain the niccolum pure, is a task of the greatest difficulty and labour. Of this you will be satisfied, when you look into Bergmann's dissertation or essay on niccolum, in the second volume of his Chemical Essays. He was at astonishing pains with it; and after all, was not satisfied that he had completely succeeded. The most highly refined niccolum that he was able to obtain by his great labour and skill was still attracted by the magnet, and had a very considerable degree of toughness or malleability. And he remained doubtful whether these qualities proceeded from iron still adhering to it, or were qualities belonging to this metal as well as to iron.

Nickel resembles bismuth in its colour,...it being white, with a cast of reddishness: and its specific gravity is about 8,66.

When it is exposed to the action of the air and heat for calcination, it is slowly calcined or oxydated in the same manner as copper:* but the oxyds procured from it are of a green or greenish colour, whereas the oxyd of copper is sooty black.

It can be dissolved by most of the acids: and its solutions are all of a pleasant green colour. In these the metals is strongly combined with the acid: and no other metal has the power to precipitate it.

It can only be precipitated by the fixed alkalis, and the alkaline earths, and by some of the compound salts or saline compounds which contain some of the acids, for which this metal has a strong attraction, and which form with it insoluble compounds. The metal is combined with such acid in this case, in consequence of a double elective attraction, and precipitates with it.

When it is precipitated by alkalis, it is necessarily in an oxydated state; and in this state can be redissolved by adding more of the alkali. The volatile alkali especially dis-

* Cronstedt says that, when strongly heated, it emits sparks, or brandishes like iron.

solves it with facility ; and can even act on the pure metal in its metallic form, and always forms with it a blue solution.

In trying to mix the oxyd of nickel with vitrified earthy substances, we find that it can be employed to give a colour to glass : and the colour it gives is a reddish yellow. No other property of it relative to the earthy substances has yet been discovered.

Of the inflammables, sulphur readily unites with it, and adheres to it very strongly. It also disposes the nickel and arsenic to be more easily separated by ustulation. And a part of Bergmann's experiments for refining niccolum was founded on this fact.

Phosphorus also combines with nickel : and they adhere strongly, so as to bear a melting heat. Long exposure to this heat, and the action of air, dissipates the phosphorus, the metal all the while having a sensible fluttering glow. When it cools, so as to freeze, the phosphorus flames out very briskly. This is probably owing to the emersion of latent heat.

Nickel can be mixed with most of the other metals, excepting quicksilver, and a few others to be mentioned afterwards. And it is said that the Chinese *packfong*, which is a white metal, or metallic mixture very like silver, is compounded of copper combined with nickel and zinc. We shall take farther notice of this when treating of copper.

GENUS X....LEAD.

LEAD is the softest of the metals ; and has scarcely any elasticity or sound. It is the least ductile ; and cannot be beat into thin leaf. Its cohesion is weak. A wire one tenth of an inch in thickness breaks with $29\frac{1}{4}$ pounds. But what is very remarkable, a rod of cast lead becomes almost four times as strong by wire-drawing.

Its specific gravity is 11,35.

The fusibility of lead is familiarly known to you all. When passing from a fluid to a solid state, it has a singular intermediate state, in which it can be easily divided into very small parts or grains.* When poured then into a hot iron mortar,

* This obtains, in a greater or less degree, in all bodies, while they congeal. It does not surprise us in the brittle metals, nor in the roaching of alum, and

300 LEAD....MANUFACTURE OF SMALL SHOT.

set so as to cool very slowly, if it be continually stirred with a stick, it comes to a state in which the parts cohere somewhat like wet or greasy sand: and by stirring it now briskly, the greatest part can be reduced to the size of a coarse sand. This is called the granulation of a metal. An apparatus is made on purpose for this operation;....a sort of oval wooden box, the inside of which has partial partitions, and is rubbed all over with chalk. The melted lead is poured into this box, the lid fixed on, and the box is violently shaken for some time. This dashes the lead against the sides and partitions, and soon breaks a great deal into grains. But the other method will convert more of it into grains, because it does not cool so fast.

There is another and more curious manufacture of lead, in which it is also divided, when fluid, into very small parts. This is the manufacture of small shot. A little orpiment or arsenic is added to the lead, which disposes it to run into spherical drops, much more rapidly than it would do when pure. The melted lead is poured into a cylinder whose circumference is pierced with holes. The lead, streaming through the holes, soon divides into drops, which fall into water, where they congeal. They are far from being all spherical, however, many being shaped like pears; and must be picked. This is done by a very ingenious contrivance. The whole is sifted on the upper end of a long smooth inclined plane, and the grains roll down to the lower end. But the pear-like shape of the bad grains makes them roll down irregularly, and they waddle, as it were, to a side; while the round ones run straight down. They are received into a sort of funnel which extends from the one side of the inclined plane to the other, and is divided by several partitions, so that it is really the common mouth of several funnels, which lead to different boxes. Those in the middle receive the round grains. On each side are grains of a worse shape, but good enough for low priced shot. The grains which have gone far aside are melted again. The good ones are sorted into sizes by sieves. (*See Note 62. at the end of the Volume.*)

many other cases, where the solid is brittle, and the fluidity thin: but in viscid fluids, or even in metals with a clammy or oily appearance, it attracts more attention, and it is even thought peculiar to them.....EDITOR.

Lead is cast into sheets, by letting it run out of a box through a long horizontal slit at the bottom, while the box is drawn along the table, leaving the melted lead behind it to congeal. The Chinese cast it extremely thin in this way on cloth, for lining their chests of tea.

Lead is very calcinable. It calcines slowly in a heat a little above its melting one. Its surface is quickly covered with a dirty wrinkled pellicle, which is renewed as fast as it can be raked off. This calcination goes on most quickly at a heat rather below redness. If allowed to become too hot, the surface of the pellicle calcines in a moment to a much greater degree, forming a fluid film, which protects the rest from the action of the air.

Lead calcines much more quickly and perfectly by way of scorification. Great quantities are changed into calx by this method in the process for separating it from silver, which is generally found in lead ores. This is done in a reverberatory furnace, the bottom of which, called the hearth, is made of materials which can withstand the dissolving power of this calx. The lead is pretty strongly heated: and the fluid calx immediately forms on its surface. Two pairs of bellows blow slantingly on the middle of the melted lead; and thus blow this scum over to the other side of the hearth, where there is a channel by which it may run off. It collects in a mass of an unequal flaking texture, just as we should expect from the way by which it is forced to accumulate. By thus blowing off the scum, the air is continually applied to metallic lead, which is in a fit condition for absorbing its oxygen. But it is very imperfectly calcined; because, by running off the hearth, the air no longer acts on it. It is of a greenish yellowish colour, with here and there some ruddy streaks, where it has been more oxydated. The calx, in this state of oxydation, has some volatility: and very noxious vapours rise from it during this operation, which produce terrible effects on the human body,... bringing on, sometimes in a moment, an universal paralysis and rigidity, so that the arm that was lifted up cannot be let down again.

The calx thus formed, when allowed to cool, congeals, as I just now observed, into a mass which is not transparent, but of

a yellow colour, and plated texture, and is called *litharge*. The litharge in the apothecaries' shops is the same matter, broken into a coarse powder.

The lead gains about one-tenth of its weight by oxydation. This was the phenomenon which induced the French chemist Rey, in the 17th century, to ascribe the calcination of metals to the combination of them with air; a truth which no body attended to for more than a century. This observation was much more distinct than Dr. Mayhow's, to the same effect, on diaphoretic antimony.

This is not, however, the most highly calcined calx of lead. Litharge can be calcined more perfectly, by beating it to powder, and exposing it two or three days to a heat hardly sufficient for producing the most obscure degree of ignition. This is done also in a low reverberatory furnace: and the flame of wood rushing along it is beat down by the form of the arch, so as to play continually on the surface of the litharge. The colour of it is thus gradually changed from the yellow to an orange, and from that to a bright red, when it is called *red lead*, or *minium*.

We have here a striking example of the superior power of a moderate heat to that of a stronger one for enabling a metal to attract plenty of oxygen, and become thereby highly calcined: for this very minium, if exposed to a full red heat, gives out a quantity of vital air, returning at the same time to a less calcined state, and becoming a yellow powder, which, if the heat be increased, melts into litharge.

A quantity of vital air can be expelled from minium also, by the elective attraction of the sulphuric acid, assisted by a gentle heat. By this easily separable portion of vital air which minium contains, it has the power to oxygenate to a certain degree the muriatic acid, as Scheele has observed.

All the calces of lead are easily fusible, forming a thin fluid without viscosity; and when pure, concrete like litharge. All these oxyds, by melting them with one-eighth of charcoal, are easily reduced. Common red wafers burn and yield drops of lead. Red lead, on a bit of charcoal, is converted into lead in a moment by the blow-pipe. Dr. Priestley reduced it in ammonical gas: and water was produced at the same time. He also reduced it in hydrogen gas, and also had water. By giving

its oxygen so readily to other substances, this oxyd greatly promotes the calcination of other metals. Red lead, melted with iron filings, will be reduced, and the iron oxydated or corroded.

In the manufactures of lead work, they prevent the calcination by throwing grease or pitch upon the surface,...the operation of which is easily understood. When a private person has occasion to employ a plumber, he may observe that he never throws grease upon the melting pot, because the dross, as they call it, is considered as useless by the employer, and becomes the property of the workman. He rather encourages its formation; and contents himself with clearing the surface with a piece of deal before he casts the lead.*

The older chemical writers speak of a golden and a silver litharge. These names are given to litharge, as it is more of an orange or of a grey colour. The first is most abundant when the flame of wood is employed; and the second, when other fuels are used. These distinctions are now neglected, there being but one calx, which, when it cools greatly, is of a glassy structure, with traces of oblong crystallizations.

Such is the nature of lead with regard to heat. In trying it with the different acids, we find that this metal is affected by them nearly in the same manner as several of those we have already described.

The sulphuric acid will hardly act upon it, except the lead be in thin plates, and the acid applied strong, and with the assistance of heat. During its action, part of the acid becomes volatile and sulphurous, its oxygen being taken by the lead. And when the operation is managed in a particular manner, part is changed into perfect sulphur. The oxydated lead forms, with the rest of the acid, an insoluble sulphat of lead. Leaden vessels are useful in preparing vitriol and alum, and even sulphuric acid itself, in consequence of the insolubility of the sulphat of lead.

The nitric acid, properly diluted, dissolves lead the most easily, producing some nitrous air. It forms a soluble com-

* This observation is by Dr. Hooke, who said, in a meeting of the Royal Society, that the plumber can make it all dross, and much more, by the air with which it combines, (*Birch's Hist.*).. EDITOR.

pound, which bears to be largely diluted with water without being decomposed ; and it gives crystals which decrepitate with great noise, but do not deflagrate.

The crystals of this salt are of a singular shape, namely *triangular prisms*, like those used in optical experiments. I know no other crystals of this form. They have not a fine edge, but a narrow facet scarcely visible. These are frequently so grouped as to form hexagonal prisms, whose sides are striped or fluted, by the want of every second triangular prism, which is the primitive molecule, or nucleus, of this crystallization.

This nitrate has its ingredients but weakly united. A moderate heat long continued will expel the acid from it,... leaving a fusible oxyd in the retort.

The muriatic acid, in its ordinary state, acts but very slowly and imperfectly on this metal. Woulfe says that some inflammable air is produced during the solution. I have never found this. It acts much more powerfully in the form of the corrosive muriat of quicksilver,...the lead being then supplied by the quicksilver, with both oxygen and acid at the same time. Or if the lead has been previously oxydated in any other way, the muriatic acid very readily joins with it: nay, it will sometimes be oxygenated by a calx of lead. Such a calx may then be considered as super-oxygenated. When, for example, we add muriatic acid to the nitrate of lead, we immediately form a muriat of lead, which is always less soluble than the nitrate.

The same thing happens if we add to the nitrate of lead any neutral salt which contains the muriatic acid. A double exchange takes place.

The qualities of the muriat of lead are, difficult solubility in water, and volatility. It is remarkably fusible, melting before it is red hot. When cold, it congeals into a semi-transparent uniform mass, called *plumbum corneum*, on account of its resemblance to a muriat of silver, which has long been called *luna cornea*, from its colour, flexibility, and a degree of softness, which allows it to be cut with a knife like horn. *Plumbum corneum* is the most powerful astringent that I know.

It is also considerably volatile, like all the metallic muriats; but has little of the butyraceous appearance which most of them have.

The acetous acid can also be combined with this metal, so as to reduce it to a saline and soluble form. But it unites much more readily with some of its oxyds than with the metal in its perfect state.

The oxyd which dissolves the most readily, is a carbonat of this metal, well known by the name of *white lead*, or *cerussa*, formed by a process contrived on purpose.

Vinegar is put into a stone-ware pot: and at the distance of two inches from its surface, there is a cross of wooden bars, on which is set a roll of sheet lead, of six feet long, six inches broad, and about one-tenth thick. It is rolled up loose, with the distance of about one-fourth of an inch between each turn. The pot is set in a bed of tan, or horse dung, and covered with a plate of lead. In about three weeks, the whole surface of the sheet is covered with a saline crust, which is detached by unrolling the lead, and scrubbing with a wire brush. The sheet is then rolled up again, and undergoes the same process till the whole is dissolved.*

Here the acid is found to have greater effect when applied in the form of vapour. A certain quantity unites with the lead, in the form of a white powder, which is afterwards much more easily dissolved. This substance, dissolved in distilled vinegar, affords salt of lead, called *saccharum saturni*, from the sweetish taste with which it affects the tongue, resembling that of sugar. It crystallizes, or rather grains, very readily. If the salt be again dissolved in more vinegar, it combines with a greater proportion of it, becomes more soluble, and affords fine crystals.

* This process merits the attention of the philosophical chemist. Dr. Black calls white lead, not a simple oxyd of lead, but a carbonat: and in fact, white lead contains a very great quantity of carbonic acid, and this acid seems to be combined with the lead. The insolubility in water does not prove that white lead is not a combination of the metal with an acid; for we know others, such as the sulphat of this metal, not more soluble. How does the lead acquire this acid, and what is the nature of the vapour, after it has furnished this ingredient?... EDITOR.

With the tartarous acid, lead forms a compound very insoluble. It may be produced by boiling a solution of tartar, and adding any pure oxyd of lead. The superfluous acid of the tartar joins with the lead, as with chalk, and forms an insoluble sediment: and the tartar is thus neutralized, being deprived of the acidulating part of its acid.

Or if, instead of an oxyd of lead, we take a compound of this metal with nitric or acetous acid, and add this compound to a solution of tartar, or any liquor which contains tartar dissolved in it, the tartar is then completely decomposed by a double elective attraction; the whole of its acid uniting with the lead, to form a white insoluble precipitate.

Lead also forms an insoluble compound, in the same manner, with the acid of phosphorus, which can therefore be precipitated from urine by a solution of lead.

When we, in the next place, compare the forces of attraction between lead and these different acids, we find the strongest is that of the sulphuric acid. Other metals in general unite most strongly with muriatic acid. But in the case of lead, it is the sulphuric acid that is most strongly attracted: and when combined with the lead, it always forms an insoluble compound. It therefore precipitates lead from other acids, by joining itself to this metal in their place. This happens, not only with pure sulphuric acid, but with any salt or saline compound which contains the sulphuric acid. In however small quantity the sulphuric acid be thus applied to the dissolved lead, we have a double exchange, and a proportional part of the lead precipitates with it.

The solutions of lead, especially the acetite, are therefore, when properly used, an exceeding nice trial of the presence of the sulphuric acid, pure or compounded, in mineral waters, or other mixtures, by occasioning turbidness.

After the sulphuric acid, the muriatic is next in force of attraction for lead. As I already remarked, it separates the nitric acid, and joins itself to the lead in its place, forming the plumbum corneum, or muriat of lead.

The muriat of soda, and the muriat of lime or magnesia are decomposed by the oxyd of lead: hence the corrosion of leaden pipes. A process has been followed for procuring the fossil alkali by employing litharge. Accordingly, the decom-

position of the sea salt is accomplished; and soda is produced. But the expence would be far too great, were it not that the muriat of lead is manufactured into a fine yellow pigment, of considerable demand. The manufacture is chiefly carried on for the pigment: and the soda is a very secondary object.

Lead has also a strong attraction for the tartarous acid, and the phosphoric acid; and will quit other acids to unite with them: and they always form with it insoluble compounds. They therefore precipitate the lead from its solutions in the nitric or acetous acid, and the lead precipitates them. I made a number of experiments on such precipitations of lead some years ago; in consequence of which I found it easy to distinguish different kinds of vinegar from one another.

These compounds of the different acids with lead are all decomposed by common mild fixed alkalis, or carbonats of alkalis, and by calcareous earth.* Some of the other metals also attract acids more strongly, as zinc, which separates it in fine metallic crystals. There are also two of them that can be decomposed by heat alone, viz. the nitrate and the acetite of lead; the first, just in the same manner as the nitrate of quicksilver, with this difference, however, that the oxyd of lead is not reduced. The second may be decomposed with a heat inferior to red; and is sometimes decomposed by such a heat, in order to extract the vinegar from it in a very strong state. During this operation the lead calx is reduced: and a small quantity of inflammable fluid, resembling alcohol, is produced, and found mixed with the vinegar.

From Lemery's account of this distillation, it does not appear that much pure or strong acid is obtained. He rectifies the distilled liquor afterwards by itself, to separate the more volatile half of it, which is inflammable, like spirit of wine. The other half, he says, is called *oil of Saturn*; and is used as a detergent for the eyes of horses.

* *Queritur*. ...Is the precipitate of lead, produced by a mild alkali, the same with white lead? It is surely a carbonat: and white lead is not a pure oxyd....

But by means of the sulphuric acid, an exceeding strong vinegar can be procured from *saccharum saturni*. The *saccharum* being first distilled by itself, with a moderate heat, gives an ardent spirit; after which, sulphuric acid being added, extricates a strong vinegar.

Sulphat and muriat of lead cannot be decomposed by heat. The first melts in the fire, without separation of the acid, unless inflammable matter be made to touch it, which volatilizes the acid. The muriat not only melts, and that very easily, but also proves volatile; and will wholly evaporate without being decomposed, and cannot be reduced by inflammable matter alone.

Alkalis, in their liquid form, especially if caustic, corrode lead.

Nitre calcines it, when applied with a proper degree of heat; and converts it into a yellow powdery substance, precisely similar to litharge in all its properties.

Common salt is decomposed by calx of lead.

Sal ammoniac, distilled with granulated lead, is partly decomposed by the lead, but much more easily by the calces of lead: and this is the readiest way for *plumbum corneum*. The volatile alkali is caustic, or nearly so.

The muriat of lead made with sal ammoniac, when heated with a covered patella under the muffle, becomes pasty, and in some degree fluid, diminishing much in bulk. When it is just red hot, it begins to fume: and, upon increasing the heat still more, it becomes perfectly fluid, contracting still more in its bulk. It now emits elastic fumes. When allowed to cool, it is of a greenish grey colour, with a little transparency, and is quite brittle. When viewed with a microscope, its greyness appears owing to very small globules of reduced lead.

With respect to the earths, when they are exposed to melting heats with the calces of lead, we have an opportunity here to observe one of the most remarkable and useful qualities of the metal. This is a power which its calces have, to dissolve and melt in the fire the earthy substances, very few of which can resist this power: and they form with them glassy compounds. This property is so eminent in the calces of lead, that no earthen vessels can be contrived to contain

them melting for any length of time. Some chemists have said that they are possessed of such a secret, but do not choose to discover it. Pott of Berlin has made a vast number of experiments, in order to discover a composition of earthen vessels which can resist the action of the glass of lead. The result of his research is, that pure clay, which is free from iron, is the best. And as it must be kneaded with some dividing matter like sand, to prevent its cracking by sudden changes of temperature, the best addition is pure clay, which has already been burnt in the most intense fire. This, beaten to powder, and sorted into a sand somewhat coarse, makes a compound which will resist fusion by the calx of lead much longer than any other: but it also will imbibe it, and then will melt, as salt dissolves in water.

In consequence of this property, lead is employed in many processes, in which it is necessary to bring earthy substances into fusion, as in working the ores of the precious metals. Also, on account of its being transparent, it is employed in making the finest kinds of glass, called *flint-glass* and *pastes*. This name is given to the artificial glasses for imitating the gems. The calx of lead is eminently fitted for this purpose; because it communicates to the composition a greater refracting and dispersing power than any substance except the diamond: and to this it approaches very nearly. Unfortunately, these pastes are so very soft, that they soon lose their brilliancy, being scratched by almost every thing. This great dispersive power has enabled us to remove the defect of optical instruments by refraction, which had been long despaired of. Mr. Dollond, and Mr. Hall, a country gentleman, at the same time, and unknown to each other, discovered a method of constructing *achromatic telescopes*, by joining lenses of crown and of flint glass. There remains, however, a great obstacle to their perfection, which the superior skill of the chemist only can remove. Flint glass is never uniform in its composition. The great weight of the calx of lead seems to make it fall down towards the bottom of the pot: and when the workman takes it up, and collects it into a mass at the end of his pipe, by turning it round and round, it is collected in strata of different density and refracting power, which greatly disturbs the formation of

a fine image in the optical instrument. A premium of several thousand pounds is offered for the removal of this defect. It is remarkable that the calces of lead not only increase the refractive and dispersive powers of the glasses of which they are ingredients, but that they produce the same effect in their watery solutions. Sir Isaac Newton first observed that a solution of sugar of lead had a much greater refracting power than pure water. Mr. Zeiher, an ingenious chemist of Berlin, by increasing the dose of minium, composed a paste which scarcely yielded to the diamond in brilliancy and refracting power, and exceeded it in the dispersive quality, by which the different colours of light are separated from each other.* Minium, with a very small proportion of diaphoretic antimony, when mixed with flint, produces a paste scarcely distinguishable from the finest topaz.

Calx of lead, or glass containing lead, is necessary for making all white opaque compositions called *enamels*. Arsenic and tin alone will not do.

Flint-glass and pastes often have *veins*, or *eels*, as they are called, which differ in their refracting and dispersing power from the rest, like a mixture of syrup and water; and on account of this, are not used for mirrors. If the calx of lead be very redundant in such glass, and especially if it be not much calcined, it is of a yellow colour. It forms the glazing of common earthen ware: but it is very liable to corrosion by acids, which renders it very unfit for many culinary purposes. The solution also is very hurtful to the constitution. The common soft glazing on earthen ware is quickly corroded by vinegar: and such ware cannot be used for holding pickles. There are no vessels fit for this purpose but those of the porcelain kind, or what we call stone-ware. Till within these 30 years, it was made in great abundance in this country: and it had no glaze, but a slight

* As the difference of dispersive power in different substances is very considerable, and as it is much more remarkable with regard to some colours of light than others, it has all the appearance of being owing to elective attractions for the rays of light. It is not improbable, therefore, that there may be found a substance that attracts them all alike. Such a substance would be a most precious discovery to the optician. In the mean time, it affords another strong argument for the materiality of light....EDITOR.

superficial vitrification of the ware itself, by the vapour of soda thrown into the fire-place while the whole kiln was in a white heat. The present ware for the table, which has supplanted the stone ware, is a bibulous clay, glazed with lead: and pots for pickles and sweet-meats are made of it. But they should be rejected entirely for such uses, and we should only use the stone-ware. It is still to be had, but of a brown, or dirty colour.

Lead is easily recovered from glass which contains it. Such glass is liable to be smoked or blackened with the flame of the blow-pipe. This is nothing but the reduction of the lead.

Of the inflammable substances, several act upon lead.

Many of the oils can dissolve lead or its calces: and it is remarkable that they are dissolved most readily, and in greater quantity, by the mildest, or the unctuous oils. The solution of the calces of lead in these requires the heat of boiling water to assist it: and when they have dissolved a proper quantity, and are then allowed to cool, they form a mass which is firm and hard when cold, but which becomes soft, and tough, and adhesive, by being warmed a little. On account of these qualities, and its oily nature in consequence of which it cannot be dissolved or changed by humidity, it is very valuable.

The *emplastrum lythargyri*, or *commune*, of the shops, is made in this manner; and forms the basis of several others. A small quantity of the calx of lead is also dissolved, by boiling in the lintseed oil, which is used as paint. It makes the oil dry sooner, and leave a thicker varnish on the surface of bodies to which it is applied. Oil-paints in which the coloured calces of lead are employed, are, for this reason, the most durable pigments. White lead and lintseed-oil contracts a skin on its surface which is almost impenetrable by any action of the air and weather. Its only defect is that sulphurous and putrid steams soon blacken it. Hence it is that this brilliant white cannot be used in water colours in miniature painting.

Lead, either metallic, or in the state of calx, has also a strong attraction for sulphur. Sulphur is added to melted lead; and when mixed with it, readily unites, and forms a

compound less fusible than lead, and which in cooling produces a mass internally crystallized into glittering particles, and greatly resembling one of its ores. It is decomposed with difficulty by ustulation; more readily and perfectly by iron.

Sulphur acts also upon the oxyds of lead, and upon the compounds of these with acids, when it is applied in the form of a liquid alkaline sulphuret. The sulphur unites with the oxydated lead, and blackens it, or gives it a dark-brown, or blackish colour.

This effect is also produced by the inflammable air, or sulphurous hydrogen, that is contained in liquid alkaline sulphurets, and which separates from them in the form of a fœtid gas, when acids are added to them, or when they are largely diluted with water. The hydrogen gas having, when pure, very little attraction for water, has a tendency to evaporate from such a diluted mixture: and it carries away a small portion of the sulphur, which, if it meet with any oxvd of lead, will certainly be attracted by it, and blacken it. This is the origin of what is called *sympathetic ink*, or ink that appears by sympathy. In the course of the numberless experiments of the alchemist on lead, in the fond hope of converting it into silver, it appears that none engaged their fancy so much as those that were disgusting. Human urine, human ordure, rotten eggs, and such things, were favourite objects of research, or means of farther inquiry. When the abominable smell of *hepar sulphuris* was observed, *hepar sulphuris* was tortured by every alchemist in Europe, and its mysterious properties were innumerable. Basil Valentine discovered that rags moistened with acetite of lead became black in a few minutes if near *hepar sulphuris*: and he made a magical trick by it. If you write with a solution of *saccharum saturni*, and lay the paper between the first pages of a thick book, and put between the last pages a leaf of paper that is moistened with a solution of an arsenical preparation containing *hepar sulphuris*, the writing will become legible in a few minutes, which was ascribed to a certain inexplicable sympathy between lead and arsenic. Lemery discovered that the arsenical preparation was effectual, only because it contained *hepar sulphuris*. The hydrogen gas itself, inde-

pendently of the sulphur which is combined with it, has some share in producing this effect: and it is not improbable that the sulphur alone would not produce it. The hydrogen gas acts by reducing the lead to its metallic state, and thus disposing it to unite the more readily with the sulphur. Of the power of this gas to restore dissolved metals to their metallic state, we have many examples in some ingenious experiments made by Mrs. Hulsham. A wet mark made with liquid acetite of lead, when exposed to the hydrogen gas as it arises from iron filings and sulphuric acid, blackens immediately.

Mrs. Hulsham discovered that water must be present with the metal and acid, otherwise the reduction will not succeed. The effect of the water probably depends on its attraction for the acid, by which it promotes the separation of the metal, while the hydrogen attracts the oxygen from it. But the presence of water is not necessary to the action of sulphurated hydrogen gas. The metal is then separated from the acid by the power of two attractions acting at once; the attraction of the hydrogen for the oxygen of the metal, and that of the sulphur for the metal itself.

The same effects are also produced on the oxyds and solutions of bismuth, and rather more strongly than on those of lead. Pearl white, precipitated from the nitrate of bismuth, by the solution of cream of tartar, being rubbed on paper, and exposed to the hydrogen gas, is much more blackened than the similar preparations of lead. And these effects enables us to discover the presence of lead in various liquids in which it may happen to be concealed, as in wines especially, in cyder, and in oils and other fluids. The anxiety of the French chemists about this matter may be seen in the works of Macquer and others.

Cyder made in Devonshire was formerly liable to this adulteration: but I believe that care is now taken to avoid it in future. It was produced by putty and other preparations of white lead, which were used for filling the seams, and stopping leaks in the press-floors and vats. A better construction of them has made this unnecessary.

Relation of Lead to other Metals.

It will not mix with iron or cobalt, but unites easily with all the rest; and is employed sometimes to promote the calcination of some which are otherwise calcinable indeed, but which calcine more quickly with the lead. Of this I shall point out particular examples hereafter.

The useful compounds of this metal with others, are, 1st, Typefounders metal, in which it is the principal ingredient, but mixed with antimony. 2d, Organ-pipe metal, in which it is mixed with tin. 3d, Pewter, in which tin is the principal metal: but there is commonly some lead as an alloy to the tin; commonly too much. Nails made of a composition of three parts of tin, two of lead, and one of antimony, are hard enough to be driven into oak without being blunted; and are not rusted by salt water.

Another great use of lead is in working of the ores and metallic mixtures containing the precious metals, silver and gold. In working the ores of those metals, it produces a thinner fusion of all earthy and vitrifiable matters than any other substance. In such a thin liquid, the smallest globule of the precious metal makes its way to the bottom, which it could not do through a more clammy glass.

Iron, tin, and all other metals, except copper and platinum, are separated from the gold and silver by means of lead, by actually destroying them as metals, and reducing them to a thin vitreous slag or scoria, which is blown off the surface of the melted mass, in the same way as litharge is, or is absorbed by the porous vessel or test in which this scorification is performed. The gold or silver is left in the vessel, because it completely resists the action of heat and air, and the scorifying power of the lead. The scorixæ which are driven off, or imbibed by the test, are reduced to metal by pounding and melting it along with inflammable matters.

With regard to the ores of this metal, there is no great variety. There is only one species found in abundance, the *galena saturni*, which varies a little in its appearance. The richest is commonly that which breaks with broad and bright surfaces, and into cubical masses. Some of the varieties of

it break with less broad and more irregular surfaces, and some with such small ones, that the fracture looks more or less like that of steel. But though galæna is the principal, and only abundant ore of lead, small quantities of this metal are found in other states in the mines which abound with galæna: for example, 1st, Lead almost pure and metallic. 2^d, Calx variously crystallized and combined with fixed air; 3^d, And sometimes combined with some acids, as in green ore, &c. Some colourless crystals of this kind contain arsenical acid, and others the sulphuric.

Treatment of the Ores of Lead to extract the Metal.

If pyrites be mixed with it, the galæna must be roasted. If it be free from pyrites, it may be melted out without roasting, or roasted and melted at the same time. This is done in Scotland in very low furnaces, or a sort of open hearths. In England it is done in reverberatories.

As an article of the materia medica, this metal is reckoned powerful. As an internal medicine, it has an established character as a most powerful astringent. It is therefore used sometimes, after all other remedies have failed, in profuse hemorrhages from the uterus, the lungs, or the stomach. But it is not employed, except in cases which appear otherwise desperate; as it is certainly in itself a dangerous remedy. It is well known that the workmen employed in many of the manufactories of lead lose their health by it, and become objects of compassion;....such as those who melt it from its ores, and those who prepare colours from lead, or grind them for the painters. Such persons are seized with obstinate constipation, dreadful griping pains, contractions, and paralytic affections of the legs and arms: and as all comes on very slowly, they are not alarmed; and the profits of their employment make them continue at it till their case becomes distressing, and generally incurable.

Mr. Clutterbuck, of the college of surgeons in London, gives an account of a new and successful method of treating those affections. His method is to give mercury, which he considers as a powerful stimulant and exciting remedy, and therefore opposite to lead, which is powerfully sedative, and

often hurtful, and even mortal, by its sedative, and weakening benumbing power. A number of cases are related, in every one of which a cure was completed in six weeks at farthest. To obviate the costiveness produced by lead, he used calomel. A grain or two every night operated more certainly and easily than any other laxative. He also removed the palsy of the hands, by continuing the mercury until the mouth was a little affected.

As external applications, however, the preparations of lead are not only safe, but in the highest degree useful and salutary. The character it bears in this view, is that of a cooling sedative anodyne, and discutient medicine. A French author, Goulard, wrote two books upon it, in which he shews plainly that he is an enthusiast in his opinion of its value; but relates, in a very simple and distinct manner, cases which are very striking proofs. He recommends it highly in most external inflammations, where there is great pain or heat, and especially in paronychia, phymosis, and paraphymosis, buboes, erysipelas, when tending to mortification; the painful inflammation before mortification; gun-shot wounds that are long in healing, and all ill-conditioned ulcers; the hard painful swellings, and the ulcerations of women's breasts; all sort of fiery eruptions of the skin; and itch. In these ill-conditioned ulcers, and painful inflammations, its effects are often very remarkable in relieving the patient from pain, abating the inflammation, and all its symptoms; inducing sleep, and changing the state of ulcers for the better in every respect, and facilitating the separation or extraction of extraneous bodies from them. In some, however, it does not do service: and such are more relieved by relaxing emollient applications. I was informed by a navy surgeon, that it seldom did service in the cases of sailors. A weak solution of *saccharum saturni* is at present found the best dressing for scrophulous sores or tumours.

Mr. Goulard's preparation is made by boiling litharge two or three hours in vinegar. But as this must be of very uncertain strength, according to the different vinegars employed, we find it more advisable to use *saccharum saturni*, dissolving a scruple, or half a drachm, in a bottle of water. This gives a determinate strength, if the water be pure.

But it generally becomes milky, in consequence of some muriat or vitriolic salt contained in it. This diminishes the strength a little.

GENUS XI....TIN....STANNUM.

THIS is the lightest of all the metals, its specific gravity not exceeding 7,3. The finest English tin when melted does not exceed 7,29. Hammering will bring it to 7,3. Therefore lightness must be considered as a test of its purity. It is remarkable that when mixed in due proportion with all other metals, except regulus of antimony, the specific gravity of the mixture is much greater than what should result from the weights of the ingredients. Nay, mixed with some much heavier than itself, the mixture has a greater specific gravity than the heaviest metal. The tin must receive the other metal into its pores, in such a manner as not to increase the bulk.

The colour of this metal is very like that of fine silver: and it retains its colour and brightness in the air better than many others. It has a considerable degree of malleability, and can be hammered into very thin leaves: but it has not enough of that kind of tenacity that fits it for being drawn into wire. When thick pieces of it are bended, it gives a grating sound, which appears to proceed from some deficiency of tenacity, or some imperfect union and cohesion of its parts.

It is the most fusible of the metals; and is easily melted with a heat considerably less than the boiling heat of quicksilver. And when large quantities of it are melted, and then allowed to cool and congeal without disturbance, its parts concrete into oblong angular masses or prisms. This is seen most distinctly when a large mass or block of pure tin is broken in pieces with the strokes of a large hammer, immediately after it has concreted from a melted state, or rather before the concretion of it is quite completed. It then appears in the form of what is called *grain tin*. We can also reduce it to a powder, or to small grains like sand, by melting it in an iron mortar, and stirring the melted tin briskly and

incessantly until it be congealed. Thus we get the pulvis stanni of the dispensatories.

Tin has a strong attraction for oxygen, calcining with a very moderate heat. And from the whiteness and infusibility of the oxyds which it affords, it appears to undergo, in proper circumstances, an high degree of oxydation, which can even be carried so far by the action of the nitric acid as to convert it into a sort of acid.

The oxyds of tin cannot be melted or vitrified by themselves, and are even difficultly melted in mixture with other vitrifiable bodies. For this reason an oxyd of tin, mixed with the ingredients of glass, forms one of the best of the white enamels.*

When we dissolve tin in some of the acids, we find that while dissolving, it has some degree of power to decompose water.

It can, for example, be dissolved by digestion with sulphuric acid, a little diluted, in which it dissolves slowly: and while dissolving, it decomposes a little of the water, and produces some inflammable air, but far less than iron or zinc. The tin is thus slightly oxydated as well as dissolved; or it is combined with a small quantity of oxygen taken from the water. But when it has attracted this small quantity of oxygen, its attraction for more is diminished to such a degree that it has not power to decompose any more of the water, although it is capable of attracting a far greater quantity of oxygen when this is applied to it in a more simple state; in the form, for example, of oxygen gas, either pure, or as contained in atmospherical air. †

* This, however, cannot be made in perfection without a little lead. A glass containing lead may be whitened with tin or arsenic, or diaphoretic antimony. But if the calx of tin be added to a glass that was free of lead, it is dissolved, and becomes transparent.

† Is this conformable to the general train of chemical phenomena, or even to the particular phenomena in the oxydation of metals? It seems to be a doctrinal point; that when once a metal has combined with pure oxygen, it is then, and not till then, disposed to combine with more oxygen clogged with another substance in the form of an acid. Is the oxygen in oxygenous gas more simple than in water? It requires, in most cases, a very high temperature to begin the combination of combustible bodies with the oxygen in the gaseous form....EDITOR.

The sulphuric acid, not diluted, and applied hot, can corrode and dissolve half its weight of tin; and is at the same time changed in part into sulphurous acid, the dissolving tin attracting in this case from the acid itself a part of its oxygen. If the action of the acid be made less rapid, by diluting it with a very small proportion of water before it be applied to the tin, a portion of it can be changed into perfect sulphur, as is the case also with lead. [“But, largely diluted, it will not act upon tin.” FOURCROY.] *

The nitric acid and tin act on one another in the same manner as the same acid and the metal of antimony. The tin is not dissolved, but oxydated to an high degree, by attracting to itself the oxygen of the acid. But this action, which is slow when we make the experiment with the metal of antimony, is sudden and violent in the case of tin. The acid is violently changed and decomposed. Part is changed into nitrous acid; part into nitrous air; and a considerable part even into azotic gas.

The oxydation of tin by the nitric acid affords another distinct example of the formation of volatile alkali. Tin, as well as iron, decomposes water,...and we see that it decomposes this acid in a more remarkable manner, since it extricates pure azotic gas. That the hydrogen of the decomposed water unites with the azote of the acid, appears (in the same manner as in the case of iron) by adding a caustic alkali or lime. This immediately detaches the volatile alkali: and we perceive it by the smell, or by the cloud which it forms with the vapour of the muriatic acid. We may use, of aquafortis three parts, water five, tin leaf three, and slaked lime three. Dr. Austin was the contriver of this experiment, having first made it in another form, namely, by moistening tin leaf with the acid, and rolling it up loosely till it was corroded. He then wetted it with a solution of potash, which instantly detached the volatile alkali.

* Is the theory quite perfect here, and in some other similar instances? Tin disengages hydrogen by reason of its strong attraction for oxygen. Yet if water be added to the sulphuric acid, and thus afford a more copious and easier supply of oxygen, the sulphuric acid is, in this case, more deprived of its oxygen than when the water supplied it less liberally.....EDITOR.

This experiment, therefore, coincides admirably with the others from which we have acquired the knowledge of the compounded nature of the volatile alkali. And it is the more satisfactory, on account of its succeeding equally well when made with other metals which have a powerful attraction for oxygen, of which iron is an example.*

The muriatic acid, in its ordinary state, dissolves tin very well, and in great quantity, especially when assisted with a digestive heat. It will dissolve one-third of its weight. During the dissolution, some inflammable air is produced by the decomposition of a small part of the water, from which the dissolving tin attracts the oxygen. And if there be the smallest quantity of arsenic in the tin, which is often the case, it remains undissolved in the form of a black matter, which is metallized arsenic.

The solvent, however, which has been commonly employed for dissolving this metal is the nitro-muriatic, or aqua regia. It has hitherto been employed by the dyers for producing the solution of tin necessary for fixing the scarlet dye in the cloth dyed with cochineal: and it was universally believed, both by the dyers and the philosophical chemists who wrote on the art of dying, that no other solution of tin was fit for this purpose; and that it was necessary for giving the bright red or flame colour to the dye of the cochineal, which when used alone, gives only a purplish red.

But Dr. Bancroft, who has benefited the world with a most valuable treatise on the art of dying, has shewn that these were very great mistakes. He has shewn that the bright and florid colour of the scarlet dye is not produced by the solution of tin alone, or principally, but by it and a quantity of tartar, which

* Dr. Black has omitted taking notice of what has been called the *acid of tin*, or *stannic acid*, by some late chemists. It is a singular combination of tin with oxygen, first observed by Mr. Hermstaedt. A solution of tin in muriatic acid, being boiled with nitric acid, which has been distilled from manganese, till the red fumes have ceased, is then distilled to dryness. The remaining mass is soluble in water, saturating thrice its weight. This is called *acid of tin*. It melts by a red heat, and is deprived of its solubility and acid taste, .. but long exposure to the air restores these propertiesEDITOR.

is absolutely necessary in the process, and chiefly by the acid of the tartar. The solution of tin and the tartar mutually decompose one another, by a double elective attraction: and a tartrate of tin is produced, which is necessary for the effect desired. And the doctor has shewn that a cheaper solution of tin than that produced by the nitro-muriatic solvent is fitter for this purpose. It is made by dissolving about fourteen ounces of tin, in a mixture of two pounds of the strong sulphuric acid and three pounds of the muriatic acid. This mixture may be called the *muriatico-sulphuric* solvent. It is a far cheaper solvent than the nitro-muriatic employed by dyers: and it dissolves a much greater proportion of tin.

The nitro-muriatic solution of tin is also employed for preparing from the solution of gold a fine purple or red colour, employed in enamels. For this purpose it is necessary that the tin in this solution, should be as little oxydated as possible. This condition is obtained by dissolving it slowly, a little at a time, in an aqua regia composed of four parts of aquafortis, and one of muriatic acid, diluted with an equal quantity of vinous spirit. We must keep all very cold. When enough of tin has been dissolved, the liquor has a light yellow colour. This solution must be preserved from communication with the air, both while the tin is dissolving, and afterwards; for the tin, when dissolved in any acid, especially in the muriatic, has a powerful attraction for more oxygen, and attracts it very fast from the vital air of the atmosphere, and from other bodies. This appears from many facts, and especially from a remarkable one discovered by Mr. Woulfe. He found that white arsenic in powder, put into a recent solution of tin in muriatic acid, was metallized.

We have another remarkable muriat of tin, viz. the *liquor fumans Libavii*. The French call it the *oxygenated*, or *super-oxygenated muriat of tin*. It has several remarkable properties, which we have not time to consider,...and I must refer you to Mr. Fourcroy.

To make this preparation, amalgamate the tin with one fifth of mercury, and triturate with an equal weight of corrosive sublimate. This mixture, distilled with a gentle heat, gives out, first an insipid liquor, and then suddenly produces abun-

dance of white vapours, which condense into a transparent liquor, which emits similar vapours by mere exposure to the air. I take this to be the muriat of tin overcharged with oxygen: for we have in the retort, besides an amalgam of tin and mercury, the common muriat of tin in a solid form, and needing only a greater heat to volatilize it completely.

Some experiments made by Mr. Adet give us more information concerning the nature of this singular muriat; and justify my calling it a super-oxygenated muriat of tin. A certain proportion of water, nearly one-third, added to it, causes it to become concrete. In their combination, a considerable quantity of common air is disengaged from the water, if it has not been carefully cleared of it before. Heat melts this mass: and it is then able to dissolve more tin, and in this solution no inflammable air is disengaged. Thus saturated with tin, the compound will bear a red heat without sublimation: but vapours arise, which are a muriat of tin. What remains after a strong heat, is a white calx.

From these facts it would seem, that the compound, saturated with the metal, is an ordinary muriat of tin; and the smoking liquor of Libavius is an oxygenated muriat, differing from the other as corrosive sublimate differs from calomel. Mr. Adet's notions about the consolidating effect of water are ingenious, but are not explanatory: and I think the inferences are not justly drawn.

I do not know any remarkable effect of other compound salts on tin. Nitre deflagrates with it as with other metals. The vitriolic salts are decomposed by it: and its avidity for oxygen decomposes the acid; and we have sulphur. It acts in the same manner in decomposing salammoniac: and we obtain inflammable air by the decomposition of some of the water.

None of the earths exhibit any interesting phenomena in conjunction with tin.

Sulphur combines with it in a remarkable manner. An ounce of flowers of sulphur being added to five ounces of tin in fusion, they form a black compound, much less fusible than the metal. The mixture therefore fixes as soon as the chemical union takes place. The latent heat of both ingredients emerges, and there is a bright incandescence, and the mass suddenly

catches fire. When the sulphur is in a much larger proportion, the tin seems to deflagrate.

This combination of tin with sulphur is the basis of another remarkable preparation, which long amused the fancy of the alchemists.....I mean *aurum musivum*.

Aurum musivum, or *mosaicum*, is made by various processes. The one most certain of success is the old one of Woulfe. (*Phil. Trans.* 1771.) Melt twelve ounces of tin, and add three ounces of mercury. Triturate the mixture with seven ounces of sulphur, and three of sal ammoniac. Put the powder into a matrass, and set this in the sand-pot of a furnace deeper than the surface of the contents. Employ first a gentle heat for several hours, and then raise it considerably for several hours more. In the bottom of the vessel will be found the golden scaly mass, of a slippery texture, like black lead. If the heat has been too great, or too long continued, it acquires a dark colour and striated texture. Farther up from the heat, we have cinnabar, and a compound or muriat of tin;....a volatile hepar escapes. The *aurum musivum* contains seven parts of tin and five of sulphur; and considerably exceeds half of the materials. The cinnabar is much overcharged with sulphur. The volatile hepar is but trifling. There is no mercury in the *aurum musivum*. This muriatic sublimate greatly excels all solutions of tin for giving a scarlet dye. The mercury and sal ammoniac are not essential, but improve the colour remarkably. And *aurum musivum*, prepared without mercury, does not make a good amalgam for increasing the power of an electrical machine, for which the other preparation is very remarkable. Chaptal, however, says, that this pigment, as generally prepared, contains almost one-sixth of mercury.*

Tin produces some useful mixtures with other metals.† First, it is useful for tinning iron, and copper, and brass vessels.

* *Process for preparing a beautiful Aurum Musivum.*

Precipitate nitrate of tin by a liquid sulphat of potash. Wash and dry the precipitate and mix it with one-fourth of sal ammoniac, and one-half of sulphur. Put this mixture into a retort, and give it a subliming heat.

† A mixture of tin and lead calcines faster than any metallic mixture that we know, burning like a dull peat: and the compound calx is more oxydated than either of the metals can be singly. Hence the advantage in the admixture of a small quantity of lead with the tin for making white enamel.

Tinned plate iron, or *white iron*, is a most useful production of art, as it is so easily wrought. The tin not only adheres to the iron, but penetrates it to a considerable depth; and renders it extremely soft and ductile, so that it can be forced up into any shape by the hammer, without cracking, or losing much of its pliancy.

Fine pewter is a mixture of tin with a small proportion of copper, or zinc, and bismuth. The copper gives hardness: the other two improve the colour.

A metallic mixture, which has the beautiful whiteness of fine silver, is made of tin and bismuth. It is probable that copper or iron may be easily tinned with it. I suppose some of the iron work of chariots is whitened with it.

Tin is also added to copper in different proportions, to serve different purposes, which I shall mention when I speak of copper.

I have already observed, that the calx of tin is employed for the composition of white enamels. It is a mistake in the writers on this subject to say that the pure calx of tin is the proper basis of this composition. It must contain a minute portion of lead; or the flux used with it must contain lead, otherwise it will make only a semi-transparent white. Montamy, who has written the most accurately, and indeed excellently, on enamel painting, gives minute directions for the preparation of this article; because it is used with almost every colour, in order to give to each its proper intensity. It is a most tedious process, so that the article must bear a very high price. He prescribes pure tin. But then his *fondant*, or *flux*, with which it is diluted, is *crystal d'Angleterre*, which is our flint-glass, containing lead. The common white glazing used for the cover of Delft ware is a much cheaper composition, being merely the calx of pewter carefully made, and often having an admixture of arsenic. Tassie's medallions are made of this, with a little magnesia,.... with flint, and minium, or flint-glass, for a flux.

Tin is very rarely produced by nature in its pure and metallic state: and there is no great variety of its ores. Only one kind is found in plenty. And no part of the world abounds with it so much as Cornwall. There is an exact register kept there of the produce of the tin-mines: and it appears that the average of 20 years has been about 3000 tons weight annually.

The component parts of the ore are, calx of tin, and some iron, and sometimes a little arsenic. Being thus composed

entirely of metallic matter, it is remarkably heavy: and being at the same time very hard, it is the ore which, of all others, bears pounding and washing best, and which remains the longest time in the gravel and sands, and soil, of the mountainous countries in which the veins of it are found. In such countries great quantities of this ore are procured by washing the sands and gravel of the brooks, or the soil that is near them.

After being well dressed, that is, washed clean from the matrix or sand, it is roasted, and then melted in air-furnaces, or reverberatories, with addition of some small coal to promote its reduction to the metallic state. It is afterwards assayed, to ascertain its fineness or purity: and a stamp is put upon it according to the result of the assay.

Grain tin may always be accounted pretty pure; because a very small portion of lead, which is the cheapest adulteration, and most frequently practised, destroys the tendency of the melted tin to assume that particular form. Antimony changes the form, destroying the greasy look of the fracture. Bismuth changes the crystallization still more; and is never mixed for gain.

I find nothing so effectual for clearing tin for medicinal use from the minute portion of arsenic, which it sometimes receives from the matrix, as distillation with sal ammoniac. Mercury also separates it very well. But a very long and careful trituration with water is necessary for causing the amalgam to throw out all that it contains.

Tin is used, in the practice of medicine, as a remedy to kill worms in the intestines: for this purpose it is reduced by granulation to a powder like sand, called *powder of tin*. This powder, however, has been often prepared, not from pure tin, but from pewter. And in the directions given for preparing it, by Dr. Alston, who first recommended it, in the *Edinburg Medical Essays*, we are expressly desired to take *pewter metal*. But common pewter contains a good quantity of lead: and I think I once observed colic pains, that appeared to proceed from the use of tin powders. I believe this seldom happens at present, the tin powder being now commonly prepared with pure tin.

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It may be proposed as a question, whether the efficacy of the original powders, in killing or expelling worms, depended on the tin or the lead? The lead, however never was suspected. But different opinions have been formed on this subject. The most general one has been, that the powder operates mechanically. If this be just, sand might serve the purpose better, being less heavy, and more easily moved by the intestines: and I have been told that sand is sometimes given to horses. Mr. Lewis hinted a suspicion that the tin might act by the powers of a small quantity of arsenic contained in it. But late experiments do not support this notion. They go against it: and shew that commonly tin does not contain arsenic, or so very little that it cannot produce its effect. And the truth is, that so very little, if any, of the tin is dissolved or corroded in the intestines, that it is impossible the very small quantity of arsenic which it has been found to contain should act in any perceptible manner: the opinion therefore of its acting mechanically appears the most probable: or if it be supposed to act in consequence of its being corroded or dissolved, some other preparation of it would be preferable.

GENUS XII.....COPPER.

THE obvious qualities of this metal are well known.

Of all the metals, copper is the most susceptible of condensation by hammering, or wire-drawing. For this reason, it is very difficult to say what is its specific gravity. In Muschenbroeck's voluminous table of specific gravities, we have it from 7,243 to 9000. Brisson says that copper melted is 7,788; and when drawn into wire is 8,878. This is much owing to the manner of casting. Unless poured out in a very liquid state, that is, of very great heat, it will not cast either solid or tenacious, but is cavernulous and weak. In its best state, it seems porous. It is considerably softer when just red hot, and bears the hammer. In this state it was employed in the hasty coinage of the Romans; frequently in camp, with the general's die.

It is far more ductile and malleable than any of the metals yet described; and therefore is considered as a more perfect metal. Its tenacity is also very great when wire-drawn, exceeding that of all other metals except iron. It resists the injuries of the weather much better than iron; and acquires by time an obscure glossy skin, which helps to defend it, like a varnish. There is a way to give it this sort of superficial colour by art. It is done by first polishing it, and then daubing over its polished surface the deep red oxyd of iron called colcothar, or Spanish brown, diluted with water; after which, the copper is heated to a certain degree, and the colcothar again rubbed off.

Copper, though not much inferior to iron in hardness, will not strike fire when violently driven or rubbed on flint, or other hard bodies. This is owing to its being so much less calcinable, that is, inflammable; so that, although, when a rag of copper is torn off by the stroke, it is perhaps red hot, yet it does not *kindle*, and become a source of heat to kindle other bodies. Copper is therefore employed in the powder mills for every purpose that iron is required for in other works. The hoops of powder casks, the chizels, mauls, hammers, and even nails, are all made of copper.

It requires a degree of white heat for its fusion; and in its fluid state has a bluish green colour. Melting it simply, without any addition, renders it less malleable. But when melted with a little charcoal on its surface, its malleability is preserved. When copper is urged by very great heat, it smokes; and the smoke is found to be metallic copper, (*Mem. Acad. des Sciences*, 1769, *Jan.*)

It has a great capacity for heat; and requires besides, a great quantity of latent heat to render it fluid. A consequence of which is, that when melted copper comes into contact with a small quantity of water, or watery humidity, the melted metal communicates heat to it so rapidly, and in such immense quantity, that dreadful explosions are often thus produced, by the instantaneous change of the humidity into highly elastic vapour. The most anxious care is therefore employed, in foundaries of copper, to have the moulds perfectly dry. They are even made red hot for some hours before they venture to cast any large piece of work.

When we choose to calcine copper by the action of air and heat alone, this is best done by exposing it to a red heat far inferior to that by which it is melted. The surface of it is then gradually changed into a blackish crust, which is brittle and pulverable, and gives a powder of a deep red colour. This is an oxyd of the metal, which is but little oxydated; and is very easily reduced again to pure metallic copper, by the usual means.

All the saline substances act with great facility on this metal. The more simple and active dissolve it perfectly. The more compounded or milder salts corrode it into rust.

The sulphuric acid requires the assistance of heat to make it act upon copper. Except when made very hot, it has not power to dissolve this metal: and it must also be applied in its strong state. During its action, part of it is changed into sulphurous acid, by the loss of a portion of its oxygen, which is attracted by the copper. And the metal, being thus oxydated, and then combined with the rest of the acid, assumes the form of a whitish mass, which can afterwards be easily dissolved in water, and gives a liquor of a fine blue colour, which admits of large dilution in water, without separation of the acid. From this liquor again we can obtain, by due evaporation, deep blue crystals, commonly named *blue vitriol*.

This is, therefore, the third of the compounds which were commonly called *vitriols*, which have been already mentioned in this course. The first was the sulphat of iron, commonly named *green vitriol*. The second was the sulphat of zinc, commonly called *white vitriol*. And this third one, as I said just now, is commonly known by the name of *blue vitriol*. There is also mentioned, in Mr. Boyle's works, and those of other ancient chemists, a vitriol by the name of *Roman vitriol*. This was a mixed one, accidentally formed of the sulphat of iron and sulphat of copper, crystallized together, but containing more copper than iron.

The nitric acid, in the diluted state of aquafortis, dissolves copper the most readily and quickly. The acid becomes very warm, and there is a strong effervescence, and production of a great quantity of nitrous air, into which a

part of the acid is changed, in consequence of the abstraction of oxygen from it by the dissolving copper. This nitrous air, is so pure, or nearly pure, that Dr. Priestley commoly used it in his experiments for trying and comparing the wholesomeness of different airs. It is not, however, quite so pure as that produced by dissolving quicksilver: but copper produces it more conveniently.* The compound formed by the oxydated copper and the remainder of the nitric acid is very soluble, and tinges the solution of a fine sky blue. It bears large dilution in distilled water, without separation of the acid and metal. By due evaporation, it yields crystals of a very deep and rich blue colour, very soluble, and even deliquescent.

If the crystals of the nitrate of copper be bruised, and slightly moistened, and then be hastily wrapped up in tin-foil, touching it in as much surface as possible, nitrous fumes immediately come out; the mass becomes hot; and presently catches fire, brandishing and throwing out desultory darts of flame and melted tin. It is not at all clear whence does arise the great heat in this experiment. The only chemical change that we observe is a nitrate of tin in the place of a nitrate of copper, and the eruption of nitrous fumes. Some more oxygen seems, therefore, to be necessary for the new compound: and we should rather have looked for a diminution than an increase of heat; unless we admit the heat to be produced in the same way as when alcohol or sugar is added to nitric acid.

Paper, moistened with a solution of this nitrate, when held before the fire, catches fire at a very low temperature,... not sufficient to melt tin.

* Lavoisier says that when the copper is put into this acid in small pieces, so as to present an extensive surface, the action is exceedingly violent; the acid is rapidly decomposed; and, after the eruption of much gas, there is a sudden re-absorption, and ammonia is produced. This is a curious, and a somewhat embarrassing fact. Whence comes the hydrogen? for we know that a tube of pure copper, red hot, does not decompose watery vapour. If, indeed, water be decomposed, and hydrogen disengaged, the re-absorption might be attributed to its combination with the azote disengaged from the nitrous acid, had we not learned from Dr. Austin's experiments, that although gaseous azote will combine with nascent hydrogen, gaseous hydrogen will not combine with nascent azote...EDITOR.

These crystals are very fusible ; but it is a sort of watery fusion they undergo ; for they are very retentive of water. And if we increase the heat a little too high, the acid begins to evaporate, and carries away a small portion of the copper.

The muriatic acid dissolves this metal slowly. The colour of the solution is at first dark brown, but becomes green by keeping. Sympathetic, or rather changeable ink, of Mr. Macquer, is prepared from this solution.

The solution, when duly diluted, has a light blue colour; and when spread on paper, exhibits the same hue as long as any moisture adheres to it. But when slowly dried before the fire, and allowed to attract the moisture again, it returns to its former state of an almost imperceptible blue. In order to insure the disappearance when cold, dip a pencil in the solution (very weak) of muriat of lime. Pass this over the copper solution: it will not decompose it, but, by attracting moisture, will cause the colour to vanish almost entirely. Care must be taken with this, and indeed with all those sympathetic inks, not to let the paper become too hot. This scorches that part on which the solution is spread, and makes it a permanent brown.

The scales of copper, formed by calcination, exhibit nearly the same appearances in solution in this acid. A recent and brown solution of the scales, if largely diluted with water, deposits part of the copper in the form of a white precipitate, super-saturated with copper. This white precipitate, if immediately dissolved in fresh acid, gives a brown solution, which, like the brown solution of copper, or of the scales, becomes green, if exposed to the air; absorbing oxygen from the atmosphere, becoming more calcined, and more soluble.

Hence we may conclude, 1st, that the scales are very moderately calcined ; and that metallic copper undergoes nearly the same degree of calcination, when forming a brown solution in the muriatic acid. 2^d, That copper cannot be more calcined by mere heat and air, its surface being already neutralized. But if the copper be divided by solution, and exposed simply to the air, it absorbs more oxygen : and the solution becomes green.

The vegetable acids do not dissolve copper readily in its metallic state. The confectioners have observed that acids, syrups, and pickles, made with vegetable acids, do not acquire a bad taste from copper vessels, if only boiled quickly, and not allowed to cool in them, or to remain after cooling. It is only when we apply such acids to copper in the state of an oxyd, that they have power to dissolve it. But an oxyd is very soon formed, if these acids or any saline substance whatever, is applied to this metal, while air is allowed at the same time to act on it. A green or blue rust is soon formed, which is mostly an oxyd of this metal, in an highly oxydated state, and very soluble in vegetable acids. And the reason why these may be hastily boiled in clean copper vessels without being tainted, is, that there is not time nor sufficient action of the air for the formation of an oxyd.*

Verdigrise is an acidulous oxyd or rust of copper, produced by art, prepared much in the same manner as the *saccharum saturni*. It is also prepared in a coarser way, by taking what remains in the winepress, after the must has been entirely squeezed from the grapes, adding some soured wine, and stratifying this mixture with plates of copper. As the husks grow sour, the copper is corroded: and after some weeks of this treatment, the saline crust is beaten off by the hammer. This coarse preparation is then dissolved in weak vinegar, with the addition of some more copper; and lastly the crystals are purified in the usual manner.

This substance dissolves readily in distilled vinegar; and gives a liquor of a deep green, which being evaporated, affords crystals of the same colour: but the powder of them is bright and elegant, like that of all semi-transparent bodies. Hence it

* This co-operation of the air, in the slow solutions, or rather oxydations of copper, is unquestionable; and is the source of some very curious appearances, which have long puzzled the chemists, but are now pretty well understood. It is not peculiar to copper: but its effects in the case of copper are more remarkable. But it is surely a difficulty in the theory. It is unlike the whole train of chemical phenomena, that a partial combination with any particular substance should increase the disposition to combine with more. There still lurks some yet undiscovered agent. ...EDITOR.

is used by painters, though they find it corrosive. The name they give it is very improper.....*distilled verdigrise*.

All these compounds of copper with acids, when they are thrown into the fire, or mixed with flaming fuel, give a green or blue colour to the flame, and noxious fumes.

If we desire to decompose these compounds of copper with acids, we can effect the decomposition of some of them by heat alone. Others can scarcely be decomposed without the aid of an elective attraction.

The one which is the most easily decomposed by heat alone, is the acetite of copper. This must be done by distillation of the dry materials, that we may obtain the acid as concentrated as possible. As a dry powder cannot communicate the heat so quickly and perfectly to the interior parts, as a fluid body can do, this distillation always destroys some of the acetous acid. The first part of the produce is tainted with a small portion of copper, which gives it a green colour: and before the production of acid vapours is much abated, there is a very sensible empyreuma. We therefore do not obtain nearly the whole of the acid in a state which can be purified. The taint of copper is easily removed by a rectification. But the empyreumatic smell cannot be taken from a considerable portion, obtained about the end of the distillation, when the bottom of the retort is even red hot. If this be left out, we obtain the acid in a very concentrated state, having a very pungent, but agreeable odour; inferior however to that which may be obtained, by a careful dephegmation of vinegar concentrated by freezing.

From sixteen ounces of crystallized verdigrise we may obtain three ounces of water, and six and a half of acid, of which five and a half are (after rectification) free from copper and from empyreuma. There is a residuum of five ounces and three quarters, and a loss of nearly an ounce. This loss is sustained before the strong acid comes over.

Mr. Berthollet has shewn that it is a more powerful acid, and has a stronger attraction for alkalis than common vinegar; and that this is in consequence of its receiving oxygen from the oxyd of copper, which is reduced nearly to its metallic state during the distillation, and is generally a pyrophorus. (*See note 63. at the end of the Volume.*)

Of the other acids, only the nitric acid can easily and perfectly be separated by heat;* the sulphuric acid difficultly. The muriatic acid is not separable by heat alone; but rather renders the copper volatile along with itself.

But alkaline salts, and alkaline earths, precipitate the copper: and some of the precipitations deserve notice.

1st. Lime-water is sometimes employed to precipitate copper from some of its solutions; and gives a precipitate, which is an oxyd of the metal, combined with a small quantity of the lime, of a pleasant light blue colour, and is called *verditer*. It is employed by the painters. The French call it *cendres blues*,...blue ashes. The copper is first precipitated exactly by quicklime: and then from seven to ten *per cent.* of quicklime is ground with the calx and a little water.

2dly, Dr. Scheele has taught us another way of precipitating the copper, by which we obtain another colour useful for painters.†

When alkalis in their ordinary state are used, the copper is precipitated in form of a very pale or whitish-green oxyd, which can be dissolved again by adding more of the alkali than what

* If the acid so obtained be condensed in a receiver containing a solution of caustic fossil alkali, it forms a nitrate of soda, differing exceedingly from that formed by dissolving soda in nitric acid. I could not bring it into a good state of crystallization; nor would it form cubical crystals at any rate, but coalesced in flakes, which felt slippery and soft.

† Mr. Scheele's process is nearly as follows.....Dissolve two pounds of the blue vitriol in a copper kettle, over the fire, in about six quarts of pure water. Dissolve in another vessel two pounds of dry potash, and eleven ounces of pulverized arsenic, (N. B. what is sold ready pulverized is generally adulterated with gypsum) in two quarts of water, also over the fire. When all is dissolved, strain the solution through linen.

Pour this arsenical solution into the solution of blue vitriol, stirring the mixture all the while with a wooden spatula. Let the mixture stand quiet some hours, that the green colour may settle. Then pour off the clear liquid, and edulcorate the sediment with repeated hot waters. At last the green pigment is obtained by draining it through a linen cloth, hanging loosely between four sticks; and then it is dried on blotting paper, or a chalk stone. By this process we obtain one pound six ounces of the powder.

The most careful edulcoration is necessary; for if it retain any of the alkali, it will not work with oil as a paint. It makes a very elegant and lively green.....EDITOR.

is necessary to saturate the acid; the superfluous alkali acting on the metal as a solvent. This is most remarkable when we use the volatile alkali.

The volatile alkali has this power of a solvent with respect to all the purer oxyds or rusts of copper, and acts, though more slowly, even on the metal in its metallic state. And the deepness or richness of the colour is such, that it enables us to detect a very small quantity of copper in any mixture. One-hundredth of a grain will sensibly tinge a pound of water.

The action of ammonia on copper, or its oxyds, presents a very remarkable phenomenon. If a solution of caustic volatile alkali be poured on copper filings, we have in a short time a solution of a beautiful blue. If a bottle be filled quite full of the solution of alkali, and we put in some filings, and immediately put in the stopple, we shall not have any sensible blue colour till after a very long while. When ammonia is in a vessel not quite full, and has acquired this blue colour, it loses it by long keeping when the vessel is all the while close. But if we open it, the blue colour begins to appear at the surface; and in time it penetrates to the bottom. Closing the vessel causes it to lose the colour completely after some time: and it will again return when the vessel is left open. And this may be repeated several times before it becomes permanently blue. Chemists attempt to explain these appearances, by observing, 1st, That when the alkali has become saturated with copper, the solution is permanently blue; 2d, The solubility in alkali increases, as the metal is more oxydated, to a certain degree; 3d, The action of the air contributes greatly to the oxydation, when there is something at hand ready to take up the oxyd. Therefore the first solution is that of a very minute portion of copper at the surface; all below has such an excess of alkali that it is colourless. When the vessel is now closed, the copper, which is more abundantly dissolved at the surface, diffuses, and is again combined with an excess of alkali, and grows colourless. Now open the vessel,...the superficial parts become more oxydated: a greater quantity is dissolved: and the colour re-appears, and will reach the bottom, if the vessel be kept open; if not, the copper again diffuses till the solution is

again equable, with excess of alkali, and colourless. This may go on till *all* the alkali is saturated, when the colour becomes permanent.

Alkalis, therefore, have the power to dissolve copper, as well as to precipitate it from acids. They shew this power also when applied to it in the way of fusion; but act more easily on the oxyds than on the pure metal. And not only the alkalis alone, but any glass that contains them, acts upon those oxyds, and dissolves a certain quantity of them. The glass is thus coloured by the copper combined with it: and the colours it assumes are either transparent blues or greens, more or less similar, to the colours of the solutions of copper: or, when a great quantity of this metal is combined with the glass, the colour of the mixture is an opaque red. The beautiful greens that are seen in the figures and foliage on the glazings of pottery are generally done with copper.

Another precipitation of copper from its solutions, which deserves notice, is the precipitation by iron. The copper is precipitated in its metallic form, as in many other cases of the precipitation of one metal by another; the iron attracting both the acid and oxygen at the same time. This manner of precipitating the copper is practised in some places with the waters of mineral springs, which flow through veins or mines of copper ore, and which contain a small quantity of blue vitriol dissolved in them. This is in some places so abundant, that they are treated for the copper they contain, by putting old iron into the gutters in which they run,...the cupreous mud which settles on it is collected and reduced to metal in the usual manner, by a very small quantity of inflammable matter and flux.

Sulphur unites readily and strongly with copper, when they are properly mixed, and made to act on one another with the assistance of heat: and while they are uniting, a quantity of heat is extricated from them, which suddenly produces in the mixture a remarkable and bright degree of ignition.

Some very remarkable experiments were made by the Dutch chemists, Van Troostwyck, Deiman, and others, which occasioned considerable surprise, and led some to call in question the theory of combustion published by Mr. La-

voisier. It appeared that bodies could burn without the absorption of oxygen. For the heat and incandescence produced in these experiments were so remarkable as to be mistaken for a real inflammation in close vessels. When three parts of copper are mixed with one of sulphur, and are rammed into a small narrow-mouthed phial, and exposed to a heat gradually raised to redness, the mixture swells, and then almost in a moment, becomes luminous all over, and bursts out into a violent flame. Zinc and sulphur require a stronger heat, and give a brighter flame: so do iron and sulphur. This experiment succeeds equally well in *vacuo*, in carbonic acid, in azotic, or in hydrogenous gas. (*See Exper. Phys. et Chym. par V. Troostwyck, Deiman, &c. Amsterd. tom. iii.*) But since these facts have been more carefully examined, it appears that it is not an inflammation or combustion, but merely an incandescence, arising from a copious emergence of latent heat,...the compounds are totally different from those formed by real combustion. They have not, however, been sufficiently examined, though very interesting.*

The compound, when the parts of it are completely united, is a dark leaden-coloured mass, which is quite brittle, not in the least malleable; and I suspect that a great part of that heat which was extricated from it was the latent heat, which gave toughness and malleability to the metal in its separate state. The sulphur is not easily burnt out of this compound. There is less difficulty in freeing iron from sulphur, although iron is supposed to have, and has in reality, a stronger attraction for sulphur than copper has. The reason why the sulphur is not so easily evaporated from copper is, that this metal is not so calcinable by heat as iron, and can be calcined

* I think that it may be inferred from this, and many similar facts which have already come in our way, that the oxygenous gas is not the sole source of the heat and light which emerge in the combustion of bodies. In the union of sulphur with dry filings of iron, copper, zinc, lead, tin, silver, and with running mercury, there is no oxygenous gas, nor gas of any kind in action, and yet a very great deal of heat and light escape from the bodies. Not to call this combustion is, at best, philosophical affectation and fastidiousness. It is not oxydation,...nor is the union of azotic gas with oxygen combustion. So to misname the one is ignorance, and so to misname the other is pedantry.

only to a very moderate degree. In this moderately calcined state, it retains the sulphur strongly, and parts with it slowly; whereas iron, when joined with sulphur, forms a compound, in which the iron is very easily calcinable, and to a high degree. It has a strong attraction for oxygen or vital air; and when the iron is highly calcined, its attraction for sulphur or the sulphuric acid, is greatly diminished,....the calces of metals which are highly calcined, having in general but little attraction for sulphur or acids. But although we cannot so easily and quickly burn and evaporate sulphur from copper, it may be burnt out and evaporated from it by a slow and skilful ustulation or calcining process, continued for some time. The first effect of it is to change the sulphur into acid, which remains adhering to the copper, and makes it soluble in water into a blue liquor, from which blue vitriol may be obtained by crystallization; or if, instead of dissolving the calcined matter in water, we roast it further with a stronger heat, we can evaporate the sulphuric acid, and have at last an oxyd of copper, nearly in a pure state.

Some of the other inflammable substances also shew an attraction for copper or its oxyds. Several of the aromatic oils can dissolve so much as to receive a deep green tincture from it. Some of the unctuous oils also, especially when rancid, easily dissolve so much copper, or rust of copper, as is sufficient to tinge them blue or green.*. In the tallow of common candles, a small quantity of verdigrise is added to improve the colour.

The usual compounds of copper with other metals are, 1st, *paak fong*, or *paak tong*, the white copper of the Chinese, which is supposed to be copper alloyed with nickel. And when zinc is added to the compound, it resembles silver by its colour. An imitation of silver is also attempted with copper and arsenic. 2dly, The metallic compounds, of which brass guns are cast, and bells, and the mirrors of reflecting telescopes, are copper or brass, mixed with different proportions of tin. A small proportion of the tin gives the copper a yellowish colour, and makes it very hard and inflexible, although it has still sufficient toughness, and great strength. This composition is therefore employed in casting what are

* Hence the terrible effects produced by copper vessels employed in cookery.

called brass guns. A larger proportion makes it very elastic, though less tough and strong. This is used for bells. A still larger proportion of the tin forms a dense white compound, which receives a very perfect polish, but is quite inflexible and brittle as glass. This is used for mirrors of telescopes. The best composition for the mirrors of telescopes was discovered by the industry of Mr. Edwards, and published in the *Nautical Almanac* for the year 1787. You will find an account of it in *Nicholson's Chemistry*, where he mentions the combinations of copper with other metals. The ancients made use of tin very much, as an alloy of copper, and in the composition of their brass, for their arms and cutting instruments, which required great hardness. It is deficient in toughness: but this is considerably improved, as I am informed, by passing it between the rollers of a flatting mill.

There is something curious in the process for whitening pins. It is commonly believed that this is done by mercury. But it is a coating with tin, incomparably more durable.

Copper, dissolved in any acid whatever, is precipitated completely by tin. Yet in this process the tin is precipitated by the copper. The effect depends on the attraction of pure or metallic copper for pure or metallic tin. The tin is first dissolved by a mixed solvent, which contains some tartar; during which dissolution, the tin is slightly oxydated: and this solution alone does not whiten copper in the least. But if fresh tin, or a small quantity of iron, be added while it is boiled with the copper, the fresh tin, or iron, by their attraction for oxygen, deoxydate the dissolved tin, or deoxydate a part of the water, the hydrogen of which deoxydates the dissolved tin, which, before it has time to form coherent particles by itself, is attracted by the surface of the copper, and adheres to it. Mr. Gadolin tinned gold in this manner, although the solvent he used could not act in the least upon gold.

Of solvents for such a purpose, when a bright and shining surface is required, rather than an high degree of whiteness, the solution of tartar is to be preferred. The solution of alum gives merely an exquisite whiteness; but it is a dead

white. If tartar and common salt are added to the alum, they take off the deadness of the white, and give some polish and brightness. One part of white tartar, two of alum, and two of common salt, form the best solvent. The solvent should not dissolve any of the copper. If any part of the copper should be dissolved, it would frustrate the process. (*Nicholson's Dict. p. 947.*)

This metal is also alloyed with zinc, to form pinchbeck, brass, and similor. Copper, mixed with zinc, in the proportion of two parts of copper to one of zinc, forms brass, which has a light greenish yellow colour, and when made red hot, becomes quite brittle. I have already described the process for making this compound by cementation. But with equal parts of zinc, the copper forms a Bath metal, or similor, which is malleable when heated, like iron. And if a little iron, or cast steel be added to this compound, the mixture proves as malleable when heated as iron, and as strong and difficult to bend and break when cold. They are, therefore, making trial of it now for bolts in building ships of war. Copper, in the proportion of three or four parts to one of zinc, makes pinchbeck. Similor has a rich yellow colour, and in consequence of its softness and malleability when hot, is formed into all sorts of goods at Birmingham, by stamping or coining.

Copper is also the most fit metal to be used as an alloy to silver and gold, to give these metals stiffness and hardness, without diminishing their toughness too much.

The relation of lead to copper is somewhat particular. Copper does not mix with lead, unless the lead be heated to the boiling or scorifying degree. The copper then sinks in, and is dissolved very quickly; but if allowed to cool, separates in some measure, so that the mass becomes like sand and water. When copper and lead are mixed, they are therefore easily separable; first by eliquation, then by skimming the lead, which will make it sufficiently pure from the copper; and as the copper still retains a little lead, this is worked off by scorification. Copper is separated from other coarser metals in general by scorification, especially with lead.

Natural History of Copper.

Copper is frequently found in its metallic state, and nearly pure, in the form of plates or fibres, or branched masses, or irregular lumps, intangled in the matrix of the vein. In the inland parts of North America, there are rich veins containing copper in this form. It abounds in the same state in some of the islands that are to the west of North America; and is found more or less in many other parts of the world.

Professor Robinson told me that an old officer in the Russian service who was with Captain Bering in the first voyage from Kamtschatka to America, informed him that on the beach in Bering's Island there lay an immense quantity of metal, rounded like pebbles by the washing of the sea, which were all malleable copper. He thought that many ships might be loaded with it. This has probably been a volcanic production; for Kamtschatka, and the whole cluster of islands between it and America, seem to have been raised by the same cause. I also suspect that it was rather an ore, or an oxyd, than the native metal which was seen at Bering's island. The western district of the Siberian mines contains many horizontal strata of copper gravel, in which are found plants and trunks of trees (all exotic) completely penetrated by the copper.

But it occurs much more frequently in the form of ores, of which there is a considerable variety and abundance. Anglesea contains the richest bed of copper perhaps in the world; and of late years, yields about twenty-five thousand tons of metal annually. The vein is about seventy feet thick.

In taking a cursory, but comprehensive view of the ores, they may be distinguished into three principal kinds:

1st, The natural oxyds of copper.

2d, The grey ores of this metal.

3d, The yellow ores.

The most remarkable natural oxyds are of four varieties;

1. The deep red oxyd of copper.....*minera vitrea rubra*.

2, The blue oxyd.....*minera lazurea*.

3. The green oxyd....*minera viridis*.

4. The fibrous green oxyd, named *malachites*.

The second general section of the ores, the grey ores, comprehends those in which the copper is combined with sulphur, arsenic, and other metals, but is itself the most abundant ingredient in the compound. Iron is generally contained in these ores, and often some silver. If the silver is in such quantity that the extraction of it is a profitable business, they are often named *silver ores*.

The third general section comprehends the yellow ores, or copper pyrites. In these, the copper is not the most abundant metal, iron being present in greater quantity, together with much sulphur, and often arsenic; but the copper is in such quantity, that it is the most valuable ingredient, and is the only one which gives value to these ores. They have a yellow colour and metallic lustre, like that of brass, or a little resembling that of the common pyrites, which contains iron and sulphur only, but are easily distinguishable from the common pyrites by obvious differences. The common pyrites is so hard that a knife or file makes no impression on it; and it scratches glass, and strikes fire with steel. The copper pyrites is so soft that a knife easily makes impression on it, and scrapes or scratches the surface of it. They are also remarkably different in colour. The yellow of the common pyrites is pale; that of the copper pyrites is deeper and richer, often similar to that of gold, and it is liable to a sort of tarnish, which produces the prismatic colours on its surface, as they are produced on the surface of several metals by the action of heat.

We can be satisfied by an easy experiment, whether or not a pyrite contains copper. We need only to beat a small quantity of it to powder, and ustulate or roast this powder with a low degree of red heat, by which we shall burn out the sulphur, or the greater part of it. If we then apply liquid ammonia to the remaining matter, this will immediately produce a deep blue solution, if there is copper contained in it.

As the grey and yellow ores of copper are most abundant, and are found to contain, although in various proportions, the greatest quantity of sulphur, arsenic, and iron, I shall first

describe the process by which the copper is extracted from these. To effect this separation, both labour and time are required, on account of the strong adhesion of some of these substances to the copper.

The first operations which the richer ores of this kind undergo, are repeated roastings with a moderate heat, and subsequent fusions with a stronger one. Thus the greater part of the sulphur and arsenic are gradually dissipated, and the iron is calcined and scorified, or vitrified with the earthy and stony matter that is intermixed with the ore, especially if this stony mater is quartz. This siliceous stone, when it happens to be mixed with the ore in moderate quantity, greatly promotes and facilitates the extraction of the copper, by its having a remarkable disposition to unite with calcined iron, and to be vitrified with it, or converted into scoriæ or slag. And when a rich copper ore is brangled with quartz, so much that it cannot be pounded and washed clean without considerable loss, it is usual to melt the whole, with addition of common pyrites; the iron of which being very calcinable, soon vitrifies along with the quartz, or brings it into fusion, while the sulphur, or a part of it, joining itself to the copper ore, increases its fusibility, and makes it more readily subside from the scoriæ. This manner of melting the poor or stony copper ores, is called *crude melting*, or *crude fusion*; and the product of the operation is afterwards treated as a rich ore of copper, by repeated roastings and melting processes. In England, the first roasting of the copper pyrites is performed in such a manner, that a great part of the sulphur is saved, by a contrivance which I described not long since, when I gave you the natural history of sulphur. The subsequent roastings and meltings are performed in low reverberatories, or ovens of considerable length, heated with flame. This is kept playing on the surface of the metal; and there are transverse ribs in the arch of the oven, which obstruct the direct passage of the flame to the chimney, and beat it down on the melting matter. The flame carries with it abundance of unconsumed vapour and smoke, which robs the ore of its oxygen, and leaves it in a metallic state. It is stirred from time to time, through a hole at the far end of the oven, immediately below the upright chim-

ney; thus no cold air gets to the metal, to calcine it or cool the furnace. A tap hole is opened at the side, at the lowest part of the bed; the metal flows out, with the scoriæ floating above it, and then falls into a mould, which gives it the form of a triangular prism. When this mould is full, the metal runs over into another, which it seldom fills, but has slag above it; and the rest of the slag runs over into a receptacle large enough to hold it all. I must content myself with this short description: for it would employ a session to describe these things minutely.

On the continent, a variety of furnaces are employed, which you may see described and represented in copperplates, in Schlutter's work on metallurgy, which was translated into French by M. Hellot.

When the copper is, by these operations, freed from its impurities to a certain degree, but still retains a small quantity of them, it is called *black copper*, and is very deficient in malleability; and often has not at all the colour of copper. If it contain silver, some lead is added to it in this state, and is then separated from it again by eliquation. In this process, all the lead melts and sweats out of the copper, and runs off, except a small portion, which remains inherent in the spongy mass of the copper. The silver is taken out by the lead, which has a strong attraction for it. The copper then undergoes the last operation, which is the refinement of it; and the small portion of lead which it retains, facilitates this process, and makes it more perfect.

The hearth or furnace for refining copper contains two tons, or two tons and a half, of copper, which is refined at once. The diameter of the melted metal is about three feet, the depth about two feet. A little water is sprinkled upon it from a broom. This is dissipated in vapour in an instant, and the surface of the copper is frozen. The skin is lifted off immediately with a pair of tongs, and thrown into a tub of cold water. Its under surface is of a bright rose colour, and somewhat rough and glittering by a sort of crystallization. It is called *rose copper*. This operation is continued till the whole of the copper is thus lifted off in skins.

The refined copper requires water to be poured on about forty times before the last of it is consolidated. This is a clear evidence of the great quantity of latent heat which melted copper contains, for the first water must cool the metal to its congealing point, otherwise no part of it would be congealed. All the subsequent additions of water, therefore, are necessary to extract the latent heat only, the perceptible heat continuing the same.

We have only now to add further, that in some of the states or conditions in which copper is found, it does not need all these operations to fit it for use. Such of it as is found in its metallic state, and nearly pure, requires only the operation of refinement. And the ores in which it is in the state of an oxyd, need only to be first reduced to the metallic state, and then refined.

The very poor yellow ores also, which sometimes contain no more than three, or four, or five pound of copper in the hundred weight, are often treated in a particular manner. They are first ustulated with a very low red heat, during which operation the metallic matter is oxydated, and the sulphur burnt, and changed into sulphuric acid, and part of it evaporated ; but a part remains adherent to the oxyd of copper ; and water being afterwards applied to the ustulated matter, a solution of blue vitriol is formed, which is either evaporated afterwards and crystallized, to be sold in that state, or instead of evaporating the liquor, pieces of old iron are put into it, and allowed to remain until the copper is precipitated on them, which is then collected and melted into a mass.

The preparations of copper for medicinal use, are,

Cuprum ammoniatum ;...Edin.

Pihlæ, cæruleæ ;...Edin.

For external use,

Ærugo ;...Edin.

Unguentum ex ærugine ;...Edin.

Vitriolum cæruleum ;...Edin.

Aqua styptica ;...Edin.

Aqua vitriolica cærulea ;...Lond.

Aqua sapphirina ;...Edin. and Lond.

Ens veneris, formerly in the Edin. Pharm.

SILVER AND GOLD.

WE have now considered all the metals which have been commonly known and used, except silver and gold.

These two have been long distinguished by the chemists from the rest of the metals, by the title of the more noble or perfect metals, on account of their having the metallic properties, malleability, ductility, and durability, or incorruptibility, in a much more eminent degree than the other metals.

I shall first consider the qualities by which they thus excel other metals, and afterwards those which distinguish these two.

First, therefore, their amazing ductility and malleability are qualities in which they far surpass all other metals. By experiments made upon silver, it appears that a single grain, which hardly exceeds in bulk the head of an ordinary pin, may be drawn out into a wire near nine feet long. And further, this wire, or any part of it, can be beaten out by hammering, into a thin plate or leaf one inch broad. It can therefore be made to cover 108 square inches.

Of the ductility and extensibility of gold, we have examples in the different branches of the art of gilding, or the art of covering the surface of other substances with gold. One way is with what is called *gold leaf*. And the art of beating out the gold into leaf, is very well and accurately described by Mr. Lewis. The degree of extension and thinness to which gold is brought in common gold leaf is astonishing. It is plain from the most evident and satisfactory calculations, that the thickness of gold leaf is not the $\frac{1}{288000}$ th of an inch. But gold is much more extended in manufacturing gold lace. What is called gold lace is not woven of gold wire, but of silver; the surface of which only is covered with a film of gold. To make the wire, a thick cylinder of silver, weighing forty-eight ounces, has its surface covered with one ounce of gold, and is then drawn out into wire so fine that six feet weigh only one grain. It is then flattened and twisted round silk thread, &c. While the silver is thus extending, the gold is extended along with it, so as to cover the whole surface of the silver. The wire, if examined with a micros-

cope, does not shew the smallest atom of the silver uncovered at its surface, although the gold is only one-forty-ninth part of its weight, and less than the one-eightieth of its bulk. (I find it to be the one-eighty-sixth of its bulk.) But this proportion of gold to the silver is much greater than what is barely necessary for covering or coating the wire. It is sufficient for giving it such a coat of gold as will bear some wearing before the silver appears. Mr. Reaumur had the curiosity to get some wire drawn with such a thin coat of gold, that there was in his wire only one part of gold to 360 of silver. It was drawn to the fineness of six feet to each grain, and then was flattened between polished steel rollers, which gave it a breadth of one-forty-eighth of an inch, and extended it in length one-fourth.

When our calculations end in such numbers as these, we lose all distinct comprehension of our subject. In order to understand the thinness of the gold on such gilt wires a little more clearly, I thought it worth while to compare it with the thickness of paper, in this manner:....It would take 14,000,000 of films of gold, like that on some gilt wire, to make up the thickness of one inch. *Quæritur*...What thickness would 14,000,000 leaves of common printing paper make up? *Answer*....1262½ yards, or near three-fourths of a mile. The thickness of the gold on Mr. Reaumur's gilt wire, therefore, bore the same proportion to one inch, that the thickness of a single leaf of printing paper does to three-fourths of a mile nearly, or wanting fifty-eight yards.

Another eminent quality of these metals, I said, is their durability, or the power they have to retain their metallic form, and remain unchanged, though exposed in circumstances, and to the action of bodies, which produce great changes in other metals. One example of this we have in the difficulty of calcining them. They cannot be calcined by the ordinary action of heat and air, by which other metals are calcined, nor by that of nitre, nor with the assistance of lead. In a violent heat, they remain perfectly metallic and unchanged. Mr. Boyle exposed some silver and gold in separate vessels to the fire of a glass-house furnace one month. The gold was neither changed nor diminished in weight. The silver was unchanged, but dimi-

nished by one-twelfth. Kunkel, making the same experiment, found the silver diminished only one-sixtieth; and when he repeated it with the same bit of silver, there was no diminution; from which he concludes, that the diminution in the first experiment was occasioned by impurity. Cramer also attests the truth of these facts from his own experience. It is said, however, by Fourcroy, that Mr. Macquer, by exposing the same silver in a porcelain crucible twenty times to the fires in which porcelain was baked, found it changed at last into an olive-coloured vitrified matter, which is supposed to have been a calcined and vitrified silver. I do not however find this fact in Mr. Macquer's own writings, though he relates some experiments which he and other members of the Academy of Sciences made, by exposing silver and gold to intense heats, produced by means of the best burning glasses in France. In these experiments, these metals were in part volatilized, or emitted visible vapours. These vapours were formed by the metal in an uncalcined state, as appeared plain from their condensation on the surface of silver or gold. After a long continuation of these experiments, a very small quantity of vitrified matter was formed; but Mr. Macquer justly doubts whether it was simply a part of the metal calcined. It is possible, however, that by mixing these metals with others, and exposing such mixtures to mild calcining heats, continued for a long time, some degree of calcination might be effected. But if they should undergo a slight degree of calcination by such a process, a stronger heat alone makes them immediately resume their pure and metallic form.*

When nitre is applied to silver or gold in a strong fire, provided these metals are pure, there is no deflagration or calcination of the metal. The nitre evaporates without producing any effect.

Neither can they be calcined with the assistance of lead. Lead is often employed to promote the calcination or scorification of other metals, or metallic substances; and its power de-

* The allusion, therefore, in the Bible, to this quality of the precious metal, to illustrate the triumph of a good heart over misfortune, is peculiarly beautiful; and, as this is to be seen in the book of Job, the discovery must be very ancient.....EDITOR.

pend on two particulars : 1st, The disposition which mixtures of metals have to calcine more easily and quickly than the metals in their separate state. 2dly, The great fusibility and dissolving power of the calx of lead. For when another metal, which produces an unfusible calx, is calcined by itself, its surface is soon covered over with a crust of its calx, which defends it more or less from the further action of the air, and occasions the calcination to go on afterwards slowly and with difficulty. But, if to such metal we add a certain proportion of lead, the mass is disposed to calcine faster, in consequence of its being a mixture of metals. And the calx of the lead dissolves and liquefies the other calx, and occasions it to flow off continually from the surface of the melted metallic mass towards the sides, so as to leave this surface exposed to the constant action of the air; and thus the calcination, or scorification, as it is rather called in this case, goes on much faster.

But when we make this experiment with silver or gold, there is no calcination or scorification of either of those metals. They mix easily with lead in the fire; and when this mixture is exposed to a proper heat and the action of the air, the lead alone is calcined, or scorified, and is gradually thrown out of the melted metal; for a calx and a metal cannot mix together. But all this time, the silver and gold remain unchanged, and will be found pure and undiminished in quantity, after all the lead is separated from them by the scorifying process. The eighth part of an ounce, or even a smaller quantity of either of these metals, contained in one hundred weight of lead, may be separated from it by this process.

In consequence of their power to remain uncalcined in such processes, silver and gold are often refined or purified from the admixture of other metals by nitre or by lead.

These metals are purified with nitre, by simply mixing it with them, and melting. It consumes the base metal, bringing it to the top in a scoria, which is easily worked off with a little lead. If they are much contaminated, it is usual to melt them with lead, which takes to itself the greatest part of all the other metals. The mixture is separated from the gold and silver by eliquation; and they are then treated with the nitre.

The purification by lead is usually called *cupellation*, from the sort of vessel in which it is performed. The cupel is a very flat cup, but of great thickness, made of bone ashes burnt to a perfect whiteness. These vessels are formed by filling a strong brass mould with the ashes, previously dampened a little. The depth of the mould is considerably greater than the intended thickness of the cupel, because it is necessary that all the materials be put in at once, and afterwards compressed by a piece of steel like a pestle, with strong blows of a hammer. If there has not been enough, any addition would form a layer which would afterwards separate in the heat. The face of the pestle must have nearly the convexity of a watch glass, and must be well polished.

The gold or silver is mixed with lead that is known to contain none of either of these metals. They are then subjected to a strong heat under a muffle, and to the action of a free current of fresh air. This calcines the lead, and along with it the baser metals, converting them into a thin glass, which is absorbed by the cupel as it forms. The operation is known to be finished, when the last film of lead quits the surface of the button of gold or silver, which in an instant grows resplendent. This is called its *fulguration* or *coruscation*. The practice with large quantities of metal differs from the above only in this, that the glass of lead, instead of being absorbed by the cupel, is blown off by bellows. The lead is got from the cupels again (which are expensive) by beating them to coarse powder, and reducing the lead with flux and charcoal dust.

In considering these properties of silver and gold, we might perhaps be inclined to conclude that they must be quite different in their nature from the other metals, since we do not perceive in them that affinity with the inflammable substances, which is so obvious and remarkable in the other metals.* But when we

* Is not this affinity, and their perfect inflammability, distinctly seen in their dissipation by the electrical flash? They exhibit all the appearances of heat and light, and they are dissipated in smoke, which has a very peculiar and disagreeable smell, different in each metal.

This smoke should be examined. The dissipation should be made in water which would enable us to collect it, or form some judgment by the changes which it produces in that fluid. When the combustion (for I must give it this name) is effected between two plates of glass, (even the purest and freest-

study their other qualities,...those which they shew in mixture with acids,...we plainly perceive that they have a close affinity and similarity to the other metals, and are at bottom of the same nature : for we can calcine or oxydate them by means of some of the acids,...and they produce the same changes on these acids that are produced on them by other metals. Both silver and gold, for example, can be oxydated by the nitric acid, and they convert a part of it into nitrous air. And silver can also be oxydated by the sulphuric acid, and converts a part of it into sulphurous acid, or sulphur.

It therefore appears that they are of the same nature with the other metals, and differ from them chiefly by being more difficultly oxydated, having less attraction for oxygen, and resisting completely some of the agents, by which this change is easily produced on the other metals. And when we do bring them into a calcined state by particular processes, they are capable of resuming their metallic form by the simple action of heat on them, which expels the oxygen in the form of vital air, without their requiring the assistance of any inflammable matter to attract it from them, as it is attracted by charcoal and some other inflammable substances in the reduction of most other metallic oxyds.

These are the qualities by which silver and gold differ from the other metals already described. We shall now take a view of the qualities peculiar to each of these two metals.

GENUS XIII....SILVER.

THE appearance of this metal is too well known to need any description. Its specific gravity is nearly 10,5 or 10,47.

It is never liable to have rust formed on it, but it becomes tarnished if it be not frequently cleaned ; that is, the surface of it becomes dark-coloured, as if it had been smoked, and some-

from metallic admixture) some of the gold or silver is incorporated with it. We know that metal and glass will not unite, though their oxyds unite perfectly. These facts have not been sufficiently attended to. If it be thus exploded when surrounded by azotic gas, whence comes the light and heat ?

times almost black. This happens the most certainly, and in the shortest time, when the silver is exposed to the vapours of stilphur, or sulphurous gas. And putrid vapours from rotten animal or vegetable substances (eggs especially) produce also the same effect on it. Late observations, indeed, have shewn that such putrid vapours frequently contain sulphur dissolved in them. Inflammable air alone is said also to tarnish silver, and to give to the surface of it a purple hue. This sometimes accumulates on the surface of silver to such a degree as to form a scale, which may be detached, and is found to be a compound of silver and sulphur.

Plate, when thus tarnished, may be cleaned by soap and water, but more perfectly by soot and vinegar. A solution in water of the camæleon minerale, or nitre alkalized by manganese, does it in the completest manner.

The metal is melted by a bright red heat, and when in fusion, has exactly the appearance that pure quicksilver has, reflecting with an equally bright surface the objects around it.

While it is congealing from a melted state, it is liable to form suddenly protuberances from its surface, which are sometimes branched, and are named the vegetations of fine silver. Their formation is accompanied with a remarkable incandescence, or sudden increase of ignition in the congealing silver, which incandescence is named *coruscation*, and happens in the congealing of very small quantities of melted silver, although no vegetations are formed on its surface. But these vegetations are scarcely ever formed when the quantity of the congealing silver is very small. The cause of their formation appears to be a power which silver has, as well as many other bodies, to retain the latent heat which gives it fluidity, although it be cooled to a degree considerably lower than its proper congealing point. And this happens chiefly when it is cooling slowly, and without being disturbed. At last, however, the latent heat suddenly breaks out, or emerges from a part of the fluid silver, and assumes the form of sensible heat, which produces the incandescence; and that part of the metal from which it is extricated, being at the surface, suddenly congeals. Thus a thin crust of silver is instantly formed on the surface of the mass. But this sudden formation of the solid crust being attended with the in-

crease of sensible heat, the fluid silver within the crust is expanded, and bursts through the crust in one or two places, starting up in one or more protuberances, which suddenly congeal while they are rising, and in congealing frequently throw out lateral protuberances. And thus are formed the branched figures, like cauliflowers, which are sometimes produced, and are preserved by the curious.

Most of the active salts may be combined with silver in one way or another. Sulphuric acid acts only when strong, and boiling hot. Sulphurous acid and sulphur are produced. The salt formed is of little solubility, except it contain abundance of the acid.

Diluted nitric acid is the best solvent of silver. It dissolves it with moderate effervescence, during which the metal is oxydated, by attracting oxygen from a part of the acid; and that part of the acid is changed into very pure nitrous air; the rest unites with the oxydated silver, to form nitrate of silver. The solution of pure silver is greenish at first, a common phenomenon in the solutions by this acid, which decompose the acid in part; but in a little while it is colourless. If it remain green, the silver has been tainted with copper. This solution bears dilution in pure water, and stains hair, bones, and many woods a deep and lasting black; or if weak, a brown. It gives a permanent stain even to stones; as marbles, agates, and jaspers. This stain does not appear unless the bodies be exposed some time to the light of day. The way to see this effect of the sun's light in producing the stain, is to dip a bit of chalk or marble into the solution of silver. If we then keep it in darkness, it will remain white; but if any part of it be exposed to the light of the sun, that part becomes black in a short time.* Those bodies to which the solution is thus applied, attract the acid from the calcined silver, while at the same time this metal is restored to its metallic state, or made to approach to that state by the action of the light, which expels from the calx a quantity of vital air. This effect of light, in this and some other similar ex-

* And, which is remarkable, it is much more stained by the blue and violet light than by the red and yellow, which are much more luminous and heating....EDITOR.

amples, is well known by experience; but we do not clearly understand how it is produced. We can imagine that the light joins itself to the metal, and expels the air from it. Others think that it joins itself to the air, or oxygenous principle, and restores to it the aerial form, or gives it elasticity to fly off from the metal. In consequence of this quality of the nitrate of silver, it is employed for staining hair brown, and for stamping cambrics, and lawns, and staining marbles, jaspers, &c.

By evaporation, the nitrate of silver is reduced to crystals, which are very corrosive. They melt like nitre, and they may be moulded into small cylindrical pieces, called *lunar caustic*, used by surgeons as an escharotic, and to corrode fungous excrescences.

This nitrate is perhaps the most powerful antiseptic known. Meat impregnated with it so as to acquire a sensible taste, though never so slight, will not putrefy even in a warm place. In 12000 times its weight of water, it will preserve it from putrefaction for ever; and it will separate in a few minutes by throwing in a pinch of common salt.

The muriatic acid is the most strongly attracted by silver, and will separate it from every other acid; but it has very little power to act while the silver is in its pure and metallic state. The silver must be somehow oxydated to prepare it for joining with this acid. The usual way is, to take the solution of silver in aquafortis, in which the silver has received oxygen from the acid. If we add muriatic acid to this solution, the silver instantly quits the nitric acid to join with the muriatic, and with this last forms a compound nearly insoluble in water. It therefore subsides like a curd or coagulum; and this effect is produced, not only by the pure muriatic acid, but by any saline compound whatever which contains it; such as muriat of soda, muriat of ammonia, and all other muriatic compounds, a double exchange taking place. This compound, when washed, to free it from the saline liquid, and dried, is properly called *muriat of silver* by the French chemists. It contains $\frac{5}{21}$ of acid, and has some remarkable properties; as,

1st, It is insoluble in water to that degree, that the most minute quantity of muriatic acid, or of common salt, or any other

saline compound whatever that contains muriatic acid, can be discovered in water by adding the nitrate of silver.

2dly, In the same manner as the nitrate of silver, it is changed in its colour, and some other properties, by the light of the sun, or the light of day. We have an opportunity of seeing this, if we take two portions of it new made, and keep one of them in a dark place, while the other is exposed to the light. The one kept in the dark will continue white and unchanged; the other will assume a bluish, or dove colour, and in it some of the silver will be restored to its pure and metallic state. This has often occasioned great embarrassment in the examination of mineral waters. After having indicated the presence of muriatic acid, by growing milky all over when set by, they have become brown, and the chemist was made to suspect the existence of some other taint in the water, and led into a long and fruitless investigation to find out what it was. It was the change produced by light in the lunar salt floating all over the fluid. The test of this is, that if a portion of the milky solution be set by in the dark, its colour will not change. Nor will this salt, perfectly dry and white, change its colour in air that is also perfectly dry, although accessible to light. In an experiment made by Mr. Scheele, some of it being exposed to the light, with a large quantity of water covering it, or mixed with it, the silver was restored to its pure metallic state, and the muriatic acid which was before combined with it, was found in the water which had attracted it. The evidence for this was unquestionable. Nitric acid, being poured on theedulcorated black muriat, took up all the black part of it, leaving the rest white. When some of the liquor which had been decanted from the black muriat, was dropped into this solution, as also into another solution of silver in nitric acid, a muriat was immediately formed.

Mr. Berthollet says that this salt, exposed and coloured in the sun, emits oxygenous gas very copiously, and that this also happens when the nitrate of silver blackens by the action of light under water. But Scheele also remarks, that if nitric acid be poured on the muriat, it does not blacken. The cause of all these changes is not very clearly understood. The action of the sun's light seems to expel oxygen from the solution. If this be taken from the acid, it leaves it in the state of common

muriatic acid, unable to dissolve metallic silver ; but the presence of a little nitrous acid supplies this, (itself becoming fuming) and thus prevents the deoxygenation of the muriatic, and the reappearance of metallic silver.

3dly, It is fusible and volatile, and after fusion assumes a horny flexible appearance, which has occasioned it to be called *luna cornea*.

Mr. Beaumé, however, denies that *luna cornea* has any flexibility. Indeed it has but little, being commonly shivery, and full of transverse cracks, arising from its shrinking faster in cooling than the substance to which it adheres. Kunkel, however, imagined that this is the substance of which a cup was made which an artist presented to one of the Roman emperors. He threw it on the ground, and the fine transparent glass cup did not break, but was dimpled by the fall. The artist took it up, and putting it again to rights, returned it to the emperor. It was therefore, says Kunkel, a malleable glass ; and he proposes the manufacture as a chemical problem, declaring that he was in possession of the secret. The whole is in all probability a fiction, too easily credited by Pliny or Solinus, who were but indifferent chemists. At any rate, *luna cornea* would make but a poor figure as a glass.

This substance contains the silver in a very pure state. The muriatic acid precipitates no metals from its acid solutions, but silver, mercury, and lead. Copper, which may have resisted the cupellation with lead, is thus retained in the acid. This method, therefore, is frequently employed for purifying silver. It requires some art, however, to separate it without loss from the muriatic acid. They are not separated by a low red heat ; for the compound partly escapes in fumes united with the acid, and partly runs through the vessel. It must be ground with an equal weight of fixed alkali, and bedded and covered with the same in the crucible. It is then obtained in a metallic form, and of the highest purity.*

Sulphuric acid also, added to the nitrate of silver, separates the nitric acid, and is joined to the silver in its place, forming a sulphat of silver. If the quantity of the sulphuric acid is

* I observe it said, though I do not recollect by whom, that this muriatic acid dried and triturated with calx of tin, catches fire....EDITOR.

small, or moderate, a great part of the sulphat of silver is precipitated, or separates from the fluid by a hasty crystallization; the sulphat of silver, when not super-saturated with acid, being much less soluble in water than the nitrate. But if abundance of sulphuric acid be added, the silver is super-saturated with acid, and forms a much more soluble compound, which does not precipitate. It has been usual however, to attempt to purify aquafortis by adding to it a small quantity of nitrate of silver; for if there be a little of muriatic acid in the aquafortis, it is sure to form a muriat of silver, which precipitates. And if a little of the sulphuric acid were present, it was supposed that this also would form an insoluble compound with a part of the silver, and also fall down. But this is a mistake; and the only way to have aquafortis perfectly pure is to add a little of the nitrate of silver to it, and distil it. Thus the small quantity of both the muriat and sulphat of silver which had been formed, remain in the retort, along with some of the nitrate of silver, when it is more than sufficient for separating the two acids.

In these different ways can silver be combined with the greater number of the simpler salts: even with the vegetable acids of wine, of sorrel, and of tartar. This was first done by Margraaf, in the same way that I mentioned as followed by him with mercury, namely, by applying the acid to an oxyd of silver.

I shall now inform you how it may be recovered in its pure metallic state. It is from its solution in aquafortis that we have most frequent occasion to recover silver; this metal being often dissolved in aquafortis to separate it from gold.

The recovery of the silver from aquafortis may be effected by different means; but there is but one method that is commonly practised, on account of its being convenient, effectual, and quick. This method is to precipitate the silver by copper. The copper attracts from the silver both the acid and the oxygen. The silver concretes in its metallic state on the surface of the copper, and crystallizes into a thick downy covering, which, when viewed with a magnifying glass, or with young eyes, is seen to resemble in form a thick foliage

of vegetables, or the down of feathers. The way to see this crystallization the most distinctly, is to drop some of this solution on a plate of glass a little concave, and then to put a bit of copper in the midst of it. We shall see a silver fringe form all around it in a minute; and this will continue to increase by ramifications in all directions till the whole silver is precipitated.

This forms one of the most agreeable objects for microscopic observation. A single drop of diluted solution being placed before the microscope, and a particle of copper made to touch its margin, we shall observe a stem arise immediately, protruding its branches by starts; and in five minutes, the little bush occupies the whole field of the instrument. (*See Note 30, at the end of the Volume.*)

Clock dials are silver-washed in this way. The dissolved nitrate of silver is applied to them, along with a mixture of the same with a quantity of common salt and tartar. They are then dried, and rubbed with a soft linen cloth, and immediately varnished.

While silver is thus precipitated by copper, a small portion of the copper is said to unite with the precipitated silver: but it is a very small one indeed, and such as produces no inconvenience in business. Ifedulcorated and redissolved in nitric acid, the solution becomes perfectly colourless; a sufficient proof of the purity and fitness for the most nice experiments.

Quicksilver has also been used sometimes for precipitating the silver; but the difference of their attraction for the acid is so little, that the precipitation is slow and indistinct,... they rather mix in a thick solution. The separation of the silver by quicksilver, when managed in a particular way, is attended with some amusing appearances.

Into a nitrate, formed by one ounce of silver and pure nitric acid, not greatly diluted, but afterwards diluted with twenty ounces of water, put two ounces of mercury. The silver crystallizes as it separates from the acid, forming beautiful ramifications resembling broom. It is called the *tree of Diana*. It requires thirty or forty days, and the most undisturbed repose. Much more expeditious processes, but inferior in beauty, have been published by Homborg, Beaumé,

and others*. The success depends upon the proportion of the mercury to the silver, and the strength and state of the solution.

I said that silver happens most frequently to be combined with the nitric acid. Sometimes too it is combined with the muriatic acid, by adding common salt to the solution of the silver in nitric acid. A muriat of silver is instantly formed by a double exchange, and when this muriat of silver is properly washed, and the silver recovered from it, we have it in the purest possible state.....It is recovered from this compound, as I have already observed, by grinding it with fixed fossil alkali, and exposing it to a melting heat, bedded in this alkali, and covered with it. It is of great consequence to employ the alkali in a caustic state. I find that much less heat suffices for the fusion, which is a great advantage, because a very small excess of heat volatilizes the lunar muriat; whereas, by this precaution, I have always recovered the silver without any perceptible loss.

Silver is easily separated from vegetable acids, or from alkalis, when it happens to be combined with those salts, which is never except in the way of experiment. Heat alone is sufficient to destroy the vegetable acid, and to dissipate the volatile alkali. And the fixed alkalis are separated merely by being melted.

The sulphuric acid is separated, and the silver recovered from it, by fusion with pure fixed alkali. The caustic alkali is the fittest.

The combination of silver with the volatile alkali has some very surprising properties, first observed, I believe, by Mr. Berthollet, who prescribed the following process.....Let silver be precipitated from a solution in pale nitric acid by quicklime. The calx is then to be separated by decantation, and carefully dried for two or three days, by exposure to the *light* and air. When this is stirred and mixed with volatile alkali, it separates in form of a black powder. Decant the liquor, and allow the powder to dry in the air. This powder,

* Beaumé's process is to mix two saturated solutions of silver and mercury, to dilute the mixture with distilled water, and to add a bit of amalgam. If a skeleton of a bush be made of glass, and set up in the mixture, and smeared over with as much amalgam as can be made to stick to it, the ramifications will soon cover it, and make the toy very pretty.....EDITOR.

if touched in the smallest degree, so as to press it against the vessel, and often, if merely parted so as to break a grain, explodes with astonishing violence, dashing the vessel to pieces. It far exceeds gunpowder, or aurum fulminans, and requires no heat, the most trifling agitation or friction being sufficient,....even though produced by a drop of water falling into it. We dare not attempt to inclose it in a bottle, and it must remain in the dish in which it was prepared. We should never attempt to explode more than a grain at once.

The volatile alkali employed in preparing this powder, being exposed to ebullition in a small matrass, crystallized on cooling. When one of the crystals was touched under the liquid, in order to separate it from the glass, the whole exploded and beat every thing to pieces.

Mr. Berthollet considers this as a loose compound of oxygen, silver, hydrogen and azote, having their double affinities so nearly balanced, that the slightest alteration of temperature, or even of that position of ingredients which produces the equilibrium of affinities, is enough to disturb this tottering equilibrium, in such a manner, that the superiority shall incline to that side which produces the union of the oxygen and hydrogen. The azote of the volatile alkali is disengaged, and the silver is reduced, and water is formed. The explosion is produced therefore by the azote, and from the vapour into which the water is changed in the very instant of its formation*.

This metal can also be joined with earthy bodies in vitrifications; and the colour which it gives, to glass is a beautiful yellow. It is accordingly used to produce that colour in

* The explanation is ingenious. But even in this easy case, we are not yet sufficiently acquainted with the forces which tend to continue the old assemblage, and those which tend to the production of the new, to be able to give an explanation on which the mind can rest with confidence. Were we certain that these are really the only forces in action, we could say, from the fact, that these are the prevalent forces which unite the oxygen and hydrogen. But this is all *post factum*, and we are ignorant of the source from which the heat is to be drawn. The new doctrines constantly hold forth the oxygen gas as the great source of all the heat which appears in combustion. Now in the present case, the oxygen is in the liquid or solid form already, and has none to bestow. Nor do we know any thing of the capacity of the azote for the heat. Besides, this is not a case of double affinity. The silver and azote are not united. The phenomenon is by no means explained on established principles.....EDITOR.

enamels, and the art of staining glass. And when more of the silver is used, the colour is deepened to a blood red, especially with luna cornea, which has been exposed to the light. But the colours thus given to glasses by silver are liable to change by over-heat. Leaf silver applied to common glass or plates, and made red hot with them, penetrates into them, or is dissolved, tinging them of a deep yellow colour. The lowest red heat is sufficient, and the most proper is such as will not spoil in the least any impression which the glass may have received before. A stronger heat produces a dull dirty colour, and a degree of opacity. All degrees of it may be perceived in the dissipation of a stripe of silver leaf in a strong electrical shock. The best process for this elegant enamel is as follows: Take glass of litharge three parts, flint in gross powder one part. Pour on this a solution of one-twentieth of its weight of silver. Stir the mixture till very uniform, and then dry it, carefully avoiding all dust of an inflammable or combustible nature. Melt it and pour it out. Grind it into a very fine powder. This is applied to the porcelain previously heated, and the ignition is continued under a muffle till it melts, which is observed by its glistening. The piece is taken out, and while continued red hot, it is exposed to the smoky flame of burning vegetables, which brings out the beautiful colour. (*Lewis' notes on Neuman, p. 51.*)

Sulphur may easily be combined with this metal in the usual manner, and produces a compound of a colour like lead, but duller, and somewhat soft and malleable. It is more fusible than silver. This composition so much resembles the *minera argenti capillaris*, that it is frequently imposed on collectors of ores as natural, by forming it on fragments of spar, and other usual matrices of such ores, and by conducting the refrigeration in a particular manner, which causes it in the moment of congelation to dart up slender capillary filaments, which congeal like a brush on its surface. The sulphur is separable by ustulation. Many other metals also attract the sulphur, as lead, iron, and others.

From experiments made by mixing it with other metals, it appears that all the other metals will readily mix with silver. Mercury amalgamates most readily, even in the palm of the hand, and their union produces a very sensible heat. Nickel

will not unite with it, and is, I think, the only metal which it rejects. Lead has a strong attraction for it, and will absorb the silver from iron or copper. All of them diminish its malleability greatly, except gold and copper. Tin does it most. A moderate quantity of copper does not change its colour much, but increases its hardness a little, in which quality it is rather deficient when quite pure. Hence copper is commonly added, and the quantity regulated by law to form the alloy, is about one-twelfth or one-thirteenth. Silver mixed with this proportion of copper is called sterling or standard silver. Nicholson says (on what authority I know not) that our standard admits but one-sixteenth of copper, that is, one part of copper to fifteen of silver.

When silver is mixed or alloyed with other metals, and we wish to separate them, this is done by different processes. The art of doing it completely has been studied with great attention, on account of the value of this metal, which often happens to be mixed with other metals in their ores, and on other occasions. The process is different, according to the nature of the metal combined with the silver. Thus it is separated.

1. From quicksilver; 1st, by expression, and 2dly, by heat.

2. From all, except gold or platina, by scorification and cupellation with lead, or by nitre. It is separated at Birmingham from plated copper, by boiling the plates in strong sulphuric acid, to which has been added one-tenth of its weight of nitre. The acid acts *more readily only* upon the silver than the copper, and the plates are taken out when this is thought to be effected. The silver is obtained in the form of a white precipitate, and the copper with which it is still tainted is easily separated by cupellation.

3. From gold by aquafortis, or aqua regia. This process is called the *departing*. Mr. Tillet, of the Academy of Sciences, considered this process by order of Government, with great care, and has published very valuable memoirs on the subject; and to him I must refer you, because a proper account of the process, shewing the propriety of its different parts, would take up a great deal of our time, without much addition to chemical science. Aquafortis, or aqua regia, is

employed according as the silver or gold exceeds in quantity.

These are the methods followed in practice to separate it from the metals and from gold ; and they bring it to as great a degree of purity as is ever needed for common use. But these methods do not render it perfectly pure. Scorification with lead, or calcination by nitre, leaves a little copper in it. And in separating it from gold by aquafortis, some of the copper employed for precipitating it from the acid, joins itself to the precipitated silver. Or if we separate it from gold by aqua regia, some gold is left in it.

But the process by which it is reduced to the most perfect purity, is by first purging it of all the coarser metals by cupellation with lead, or by melting it with nitre, and then making it into muriat of silver, and reducing it. Thus any gold which might have been in it, or any minute quantity of copper which the lead might have left, is separated from it. (*Vide Cramer.*)

Natural History.

Silver is found more or less in all parts of the world that are remarkable for metallic veins ; most plentifully, however, in South America, particularly Peru and Potosi.

It is found either,

1mo, In its metallic state, and pure, or nearly pure.

2do, In the form of ores, in which it is the most abundant metal, and which are called *proper ores of silver* : Or,

3tio, As an ingredient, contained in small quantity, in the ores of other metals, which are often, on account of the value of the silver, called *silver ores* ; but distinguished by the title of *improper ores of silver*.

When it is in its metallic state, it is found formed into fibres, or plates, or branched masses, often crystallized into regular figures in the cavities of the vein, or intermixed with the solid matrix. Not unfrequently it adheres to an ore of silver. The fineness of the fibres is often surprising. They affect a singular arrangement, nearly rectangular, forming chequers that are interrupted like a fret-work ornament in architecture, each being a sort of quadrangular spiral. The geologists ascribe this formation to a gradual

shrinking of the matrix from without, like what is more distinctly observed in the round balls of iron pyrites.

Of the ores of silver, the proper are chiefly three or four in number :

1. *Minera argenti vitrea*....glassy ore.
2. *Minera cornea*....horny ore.
3. *Minera rubra*....the red ore.
4. *Minera alba*....the white ore.

The first is very improperly called *vitrea*. It has neither transparency nor any other quality by which it resembles glass. It is silver combined with sulphur, and is exactly similar to an artificial compound of silver and sulphur, being soft and malleable, almost like lead, and of the same colour with metallic lead, and very fusible. The clean pieces of it contain more than three-fourths of their weight of silver.

The horny ore has been analysed with great accuracy by Mr. Woulfe. (*Phil. Trans. anno 1776.*) He found it to be silver combined partly with muriatic, partly with sulphuric acid, and there is often pure metallic silver, or sulphurated silver, intermixed with it, which darkens its colour. It is a rare sort of ore, but when specimens of it are found pure and unmixed, it bears a great resemblance in appearance and properties to muriat of silver. It then contains about two-thirds of its weight of silver.

The red silver ore is of a deep red colour, and more or less transparent, often crystallized, brittle, and very fusible. Professor Bergmann found that 100 parts of it contain 60 of silver, 27 of arsenic, and 13 of sulphur. But the proportions are a little different in different specimens; and some kinds of it are said to contain antimony instead of arsenic.

The white silver ore,....*minera alba*, has the metallic opacity and reflecting surface when broken, and a white or whitish colour, often inclining to yellow or gray. It contains the silver combined with arsenic and with other metals, as iron, copper, &c.; and the proportion of the silver in it is very various; some kinds of this ore being very rich, and others but poor. And it is subdivided by mineralogists into a variety of species. These and the improper or poorer ores of silver are accurately enumerated and described in

Mr. Kirwan's *Mineralogy*, and other works, to which I refer you ; and I proceed to give a short account of the processes by which silver is extracted from its ores.

When the silver is found in its metallic state, almost pure, and only entangled in the state of filaments, or thin plates, or grains, or branched forms, in a stony matrix, there is only one way of extracting it ; and that is, by reducing the whole to powder, or small grains, by stamping mills, or by other machinery, and macerating and working this powder in tubs with water and quicksilver, so as to give it the consistency of mortar for building. It is kept in this state for some time,...and is the better of being kept in a warm place ; after which, it is diluted with plenty of water in large wooden vessels : and a circular motion is given to this water by machinery, while more water is supplied by a small pipe. Thus the water runs out slowly, over the brims of the vessels, and carries away with it the earthy and stony part of the powder. The silver and quicksilver united together, and forming a very heavy compound or amalgama, remain at the bottom of the vessels, and are at last completely freed from the earthy and stony matter. The amalgama, which is in some measure fluid, is then taken out and dried ; and, being tied up in pieces of leather, is strongly compressed, that the fluid parts of the quicksilver may pass through the pores of the leather. These fluid parts of the quicksilver contain a little only of the silver dissolved in them, and are employed again with fresh ore. The rest of the quicksilver remains in the leather bags, combined with so much silver that it has the consistency of a stiff paste, or is almost solid. This rich amalgam is afterwards exposed to a proper heat to make the quicksilver evaporate, and leave the silver in a pure state ; this operation being so conducted that the vapours of the quicksilver are condensed by themselves in another part of the apparatus.

It often happens that the metallic silver is intermixed in the matrix with some of the proper ores of silver, and also with ores of other metals which contain a small quantity, more or less, of mineralized silver. When this is the case, the whole, after it is reduced to powder, must be subjected to a process of ustulation, by which the sulphur and arsenic

are evaporated from those parts of the silver which are in the state of ore: and the other coarser metals are oxydated, and therefore separated from the silver, which cannot be oxydated or calcined by a roasting process, but retains its metallic form, and is ready to unite with the quicksilver, in the process of amalgamation. To facilitate this, some common salt is generally added. It helps to clean the surface of the particles of silver, and thereby promotes the union of this metal with the quicksilver.

All this is detailed by different authors, who have given treatises on this particular subject, or who have described the rich mines of South America, in which the silver is almost universally found in its metallic state. The most noted of these authors are Alonzo Barba, Don George Juan de Ulloa; but above all Baron Born, who never visited America, but who, in consequence of an office he held, was induced to study the process of amalgamation, as practised in Hungary, for extracting silver and gold from their matrices. He published a book on this subject, in which he has proposed some important improvements, and described the whole of his apparatus, and illustrated his descriptions with accurate figures. It is translated into our language by the late Mr. Raspe.

When silver is found in the state of rich ores, in which it is combined with sulphur or arsenic, and with other metals, the extraction of it is commonly effected by the action of lead, and on a large cupel. This cupel is made of bone ashes, or often of wood ashes, from which all the salts have been carefully extracted. It is two and a half feet or three feet in diameter, and is formed and fixed in an iron hoop of proper depth, which limits and supports the sides of it, while some cross bars support the bottom. This large cupel in its iron frame is placed in a reverberatory furnace fitted to it, to be heated with flaming fuel; and the iron hoop is defended from the destructive action of the heat by covering it well with plenty of bone ashes, made to cohere with a little water. The flame and heat are applied to the cavity of the cupel only; the under surface is defended from the heat. A good quantity of lead is then melted, and made red hot on this cupel; and the silver ore is added to the

lead. A part of the lead immediately unites with the sulphur and arsenic, or other matters with which the silver was combined. And these matters occasion or promote the scorification of a part of the lead, which is also promoted by the wind of one or two bellows which play on the surface of the metal. The scorified lead is a powerful flux or dissolvent for the earthy and stony substances, or other metals in which the silver was involved; and the whole becomes fluid scorified matter, flowing uppermost, or around the melted and red hot metallic lead. This last powerfully absorbs the silver that has been extricated from the ore. The scoriæ thus produced are soon after drawn off by making a little gutter in the edge of the cupel, on the opposite side, from the blast of the bellows. And the lead, if sufficiently enriched, is further scorified by heat and air, until it be totally changed into litharge, the silver remaining at last on the cupel. In scorifying lead, to extract silver from it in the large way of working, the scorified lead is not allowed to sink into the cupel, or to be absorbed by it, as is done in refining small quantities of silver, or in assays. This at least is avoided as much as possible. The melted litharge is made to run out of the cupel by the little gutter I mentioned: and it drops into a cavity below, where it immediately congeals. The reason of this is, that when the litharge is pure, it is very easily reduced again into lead. But when it is absorbed into the bone ashes, it is difficult to reduce it; and it cannot be reduced without considerable loss.

These processes are sometimes varied in other ways, the reasons of which you will easily understand from what has been already explained to you. If an ore, for example, containing some silver, is very much brangled or dispersed through a large quantity of stony matter, the whole is melted among the charcoal; some other kind of sparry or stony matter being added to promote the fusion of that which involves the ore: and they add also some litharge or scorified lead, which has been produced in other processes, such as the cupellation last described.

GENUS XIV.....GOLD.

THIS metal has been distinguished by the chemists with the titles of *sol* and *rex metallorum*, on account of its excelling all the rest by the perfection of its metallic qualities ; but chiefly, I imagine, because it is the most highly prized in society.

When pure, it is soft and flexible not elastic or sonorous. I already noticed its great ductility and malleability. Mr. Lewis considers its specific gravity with great accuracy. It is about nineteen times as heavy as water : and a cubic inch of it weighs 4902 grains, or 10 ounces and 102 grains. It requires for its fusion a very strong red heat, or almost a white heat, a heat stronger than that of melting silver : and when in fusion, it emits or reflects a bluish green light from its surface.

Its surface always remains bright in the fire : and if foul or tarnished before, it is always cleaned and brightened by a red heat.

When we try it in mixture with salts, we find that none of the acids, applied in their ordinary state, produce any effect on it. The sulphuric acid, or the nitric, or the common muriatic, if applied separately, either in their watery form, or in the much more active state of dry and burning hot vapour in cementation, make no impression on it, or shew any power to dissolve it in its pure and metallic state. Upon this is founded a trick for defrauding the purchasers of gold. The bars or ingots of impure gold are cemented for a while with proper materials, which refine it to a depth proportioned to the continuance of the cementation. Trinkets treated in this manner bear to be burnished and polished ; and when tried by the touchstone appear perfectly fine. When trinket gold appears of this extreme fineness by the touchstone, it is always to be suspected as being only a crust covering base gold. An ingot, so treated, appears fine, even when cut through with a chisel, because this carries a film along with it from the surface, which covers the rest. It is proper, therefore, to cut it only half through, and then to break it.

The saline solvents which act on metallic gold, are only the oxygenated muriatic acid, and the nitro-muriatic solvent, which is therefore called *aqua regia*. The oxygenated muriatic acid is effectual in consequence of its power to oxydate the gold, which the common muriatic acid cannot do : and the nitro-muriatic acid has the same power.

This mixed acid may be prepared and applied by different ways, so as to be effectual in dissolving gold ; as

1st, By mixing the pure nitric and muriatic acids together.

2dly, By adding common salt, or sal ammoniac, in moderate quantity, to the nitric acid, and distilling this mixture.

3dly, The mixture I just now mentioned can be employed very well without distilling it.

4thly, Alum, nitre, and common salt boiled with water, form a solvent of gold, though not a strong one.

Scheele, the first discoverer of the oxygenated muriatic acid, was of opinion, that the nitric acid dephlogisticated, or, in other words, oxygenated the muriatic, and thus enabled it to dissolve the gold.

But Dr. Priestley found that *nitrose* acid, and especially the most red and volatile vapour of it, which he calls nitrous vapour, when added to the muriatic acid, occasions a more rapid dissolution of the gold than the more perfect nitric acid does, which cannot easily be explained upon Scheele's principle.

Another fact, analogous to this observation of Dr. Priestley's, is, that when the solution in *aqua regia* is going on, in a slow and languid manner, the addition of a small quantity of æther, or of alcohol, makes the solvent very active. The solution goes on briskly, and is accompanied by much effervescence. This also seems very unlikely to produce an oxygenation of the muriatic acid. It seems more fitted for depriving it of oxygen : and it is not clear how the vapours of nitrose acid should supply oxygen more readily than nitric acid, which contains more of it. Yet, from what experience I have in the dissolving of gold, and by attending to the odour of the acid when it is acting properly, I am persuaded that Scheele was right. While the acid is acting on the gold, it always gives the distinguishing pungent disagreeable odour of the oxygenated muriatic acid.

When it is saturated, the nitrose fumes are plainly distinguishable: and then the addition of a little muriatic acid immediately renews the action, and yields the smell of the oxygenated muriatic acid. The addition of a little nitric acid, when the solution flags, does not produce the same effect. From this I think the inference is plain. The muriatic acid is the basis of the solvent, but requires more oxygen, and the saturated solution is a solution in oxygenated acid. Therefore more nitric acid can do nothing. More muriatic acid can, because there is enough of nitric in the mixture to oxygenate it.

But there is also reason to be of opinion that the acid of nitre itself, when it has lost a part of its oxygen, becomes in some measure a solvent of gold, or assists in dissolving it, and that in the nitro-muriatic solvent, both acids act.

It has been found by experiment, particularly by Dr. Brandt, that a strong nitrose acid, although employed alone, will dissolve a small proportion of gold, when boiled with it some time. But, in truth, it is only a very small quantity that is thus dissolved; and even this small quantity is liable to separate again from the acid spontaneously. Moreover, when gold is dissolved in the usual manner in aqua regia, the muriatic acid adheres the most strongly to the gold, and is the principal solvent. Nitrous vapours arise from the salt while evaporating to dryness. Mr. Lewis remarks, in his Notes on Neuman, that when the solution of gold is distilled, the nitrous acid easily passes over into the receiver, leaving the muriatic alone in possession of the metal. And when gold is obtained in the state of an oxyd, by precipitation from its solution, or any other process, the muriatic acid alone, and even a weak one, can easily dissolve it, and forms a solution which has all the properties of the common solution of gold.

It is a sufficient answer to any doubts about the real solvent of gold, that the compound resulting from the solution in the oxygenated muriatic acid is perfectly the same in all respects with the salt formed by any of the compounded solvents. The nitric, or even nitrous acid may perhaps oxydate the gold, but it does not combine with it in a saline form.

The solution of gold is always of a rich yellow colour: But when applied to animal or vegetable substances, it produces an indelible stain, of a reddish purple. By evaporation, it can be made to form yellow crystals. In these the muriatic acid adheres so strongly to the gold, that it cannot be completely separated by heat. When they are exposed to heat in a retort, part of the gold rises with the acid, and is condensed into a red or deep yellow fluid, or into crystals or flowers of the same rich hue, in the neck of the retort called, by the alchemists the *red lion*.

We can easily, however, precipitate the metal from its solvent by various additions, such as alkaline salts and other metals.

Fixed alkalis and lime precipitate gold of a ruddy yellow: and the oxyd is soluble in all the acids.

Nut galls, or the gallic acid, also precipitate gold of a purple colour: and it was discovered by Mr. Monnet, that this precipitate dissolves most readily in nitric acid, giving it a fine blue colour.

The volatile alkali is one of the best precipitants of the gold, and produces the remarkable precipitate named *aurum fulminans*. It is an oxyd of the gold, which has a dull yellow colour; and is thus named on account of its disposition to explode with astonishing violence, when exposed to a very moderate degree of heat.

To see this explosion properly in its full energy, we must wash away the saline matter from the precipitate carefully with pure water, and then dry it well in a cool place. After this preparation, if we expose it to a gradual heat, it first becomes dark coloured: and soon after, if the heat be increased, it explodes with an obscure and momentary flash, visible in darkness. And when the experiment is made with a view to know what becomes of the gold, by covering it, for example, with a glass bell, it is found dispersed in small particles, and all of it restored to its metallic form.

The explosion of this preparation of gold is so exceedingly violent, that great caution is required to prepare it with safety, or to make experiments with it; terrible consequences having in some cases proceeded from the want of care or skill in hand-

ling it. Its force is such, that when so small a quantity as ten grains are exploded on a thin metallic plate, it makes an impression like that of the stroke of a hammer, or sometimes breaks a hole through it. And after it is rightly prepared, it is dangerous to treat it in any manner by which it may be heated, or exposed to friction or compression. Grinding it in a mortar, nay even the friction of the glass-stopper on a grain left in the neck of the phial in which it is kept, has been known to occasion its explosion.

It is remarkable that the heat produced in this explosion is very small. It will not singe paper. If a little be rubbed into a bit of soft spongy paper, and held over a candle, or before a hot fire, it will turn dark coloured, and then go off in a succession of cracks, with scarcely any light, and without changing the colour of the paper. I imagine that even the light arises from an electrical concussion of the air. (*See Note 65. at the end of the Volume.*)

The nature of this surprising preparation of gold, and the cause of its explosion, has been but lately even guessed at with any probability; for I cannot say that it has been discovered: and the sagacious conjecture was made by Dr. Scheele. Formerly it was supposed to contain nitrous salts, combined with the gold, and that these gave it this fulminating quality. And it is in fact a little heavier (almost one-fourth) than the gold from which it is prepared. But neither can any nitrous salts be found in it, nor is the heat at which it explodes sufficient for the explosion of nitrous compositions.

When I was engaged in making my experiments on magnesia and other alkaline substances, I had an idea that the explosion of aurum fulminans depended on carbonic acid communicated to the gold by the precipitating alkali. And this conjecture was founded on my observing that gunpowder and pulvis fulminans contained, or produced in the explosion, a great quantity of this gas. But the important discoveries which have been made since that time, shew clearly that it proceeds from a very different cause.

Professor Bergmann, in a dissertation on aurum fulminans, proves that it cannot be made without volatile alkali. If the gold be dissolved in a solvent composed of the pure nitric and

muriatic acids, and we then precipitate it with a fixed alkali, we get an oxyd totally destitute of the exploding power. But if we digest this oxyd with liquid volatile alkali, we then give it that property. And further, the pure or caustic volatile alkali serves rather better for making good aurum fulminans than the carbonat of ammonia. All this, and many other facts to the same purpose, were ascertained by Professor Bergmann.

And afterwards Scheele in Sweden, and Berthollet in France, gave us more complete knowledge on this subject, by demonstrating the presence of volatile alkali adhering to the gold in this preparation, and shewing by experiments, that this volatile alkali is decomposed when the explosion takes place. Mr. Berthollet, equally judicious in his choice of decisive experiments, and ingenious in his conclusions from them, made two experiments on these compounds, which leave little doubt as to their chemical constitution. He exposed aurum fulminans in a copper tube to a very gentle heat, gradually increased, and obtained from it great abundance of alkaline gas, by which its weight was diminished considerably, and its exploding power entirely taken away. He exploded dry aurum fulminans in a proper apparatus, and obtained water and azotic gas,....and the gold was reduced to the metallic state.

The volatile alkali is now known to be a compound of hydrogen and azote. The precipitate of gold also contains the oxygen which the metal received from the nitric acid. The attraction, however, of the oxygen for the metal, and of the hydrogen for the azote, prevents them from acting on each other until heat be applied. But when heat is applied, the oxygen and hydrogen unite with a rapid or momentary combustion, and form vapour of water with an explosion: and the azote also assuming the elastic aëreal form, the explosion is thereby increased.*

Another discovery which has been lately made, and which is connected with the subject, is, that silver can also be prepared so as to have the properties of fulminating gold, and that in a far higher degree than the gold itself. This discovery was also made by Mr. Berthollet, and has been considered already.

* I observe that some French and Italian chemists consider this phenomenon as the combustion of azote; but this is inconsistent with the experiments of Mr. Berthollet....EDITOR.

As to the formation of this curious compound, I must observe, that when the gold is precipitated in this manner from the aqua regia by alkaline salts, it may be redissolved, like the precipitates of some other metals, by adding to the mixture a superfluous quantity of the alkali. The fixed alkalis dissolve it better than the volatile alkali; and, according to Margraaf, the phlogisticated alkali is better for this purpose than the common or pure fixed alkali. These solutions are not permanent, the gold being deposited from them, especially from the volatile alkali.

If we choose to deprive the precipitate of its exploding power, and bring back the gold to its metallic state, we can effect this by several different methods; as,

1st, By calcining long, with a very gentle heat, inferior to that which makes it explode. Thus it slowly assumes a dark purple colour; and the volatile alkali is thus evaporated from it. This method requires great caution to avoid friction or concussion.

2dly, By heating it in a strong and close vessel.*

3dly, If the particles of it be separated from one another by the interposition of any powdery substance mixed with it on purpose, as sulphur, or any of the neutral salts, or earthy powders, it may be heated securely, until it is deprived of the power of exploding, and can afterwards be melted into a mass.

4thly, If some strong sulphuric acid be boiled with it, and evaporated from it, the gold remains bereft of its exploding power.

5thly, The vitriolic æther, by digestion, simply reduces a part, and dissolves a part, which is also afterwards reduced.

6thly, Muriatic acid, digested with it, dissolves it: and then, by precipitating with the fixed alkali, we obtain it no longer fulminating.

* A small quantity of aurum fulminans was shut up in an iron ball, of which it completely filled the cavity. This was exposed to a great heat, but did not explode. (*See Fourcroy*, vol. iii. p. 369. *Edin.* 1788). Can this have happened because external pressure prevented the chemical combination, as we see it prevent the absorption of caloric by water, so as to make it boil &c.

You will find it alleged in books, that washing aurum fulminans with much water, or boiling it in water, takes away its exploding power. But this is a mistake. The more perfectly it is washed, it explodes the better. And if we neglect to wash it, and thus leave in it any quantity of the salts formed in precipitating it, it will not explode well.

Such are the effects of alkaline salts on the solution of gold.

This metal can also be precipitated in some measure from its solution, by some inflammable fluids, as some aromatic oils, and spirit of wine. These liquors act by attraction for the acid.

The effects of the vitriolic æther have been thought more remarkable. It seizes on the gold immediately, and often reduces it to the metallic state, in fine films, which are rendered buoyant, even in the æther, by the adhesion of imperceptible bubbles of vital air. By adding æther to a solution of gold in aqua regia, the whole of the metal may be brought to the surface, forming a stratum above the æther; and neither of the fluids below (the æther nor the aqua regia) contain a particle of it. Generally, however, the gold remains for some time dissolved in the æther (but completely abstracted from the acid), tinging it of a rich yellow.

This effect of the æther has been the more admired, on account of its being the lightest fluid of any we know, and therefore was thought the less qualified to suspend such a ponderous metal. But the power of chemical attraction performs greater wonders than this; for gold can even be rendered volatile by some of the salts which have the strongest attraction for it. And in this case of the dissolution and suspension by æther, the æther acts more by its attraction for the acid with which the gold is united, than for the calcined gold. But it appears also to have some attraction for the oxydated gold itself. Mr. Lewis and others say that aurum fulminans can be dissolved by it at least in part. Still, however, I am inclined to suppose that the æther acts, even in this case, by its attraction for the oxygenous principle, and the small quantity of saline matter combined with the gold; for it is certain that when we apply it to pure gold in its me-

tallic state, it has not the least power to act on it, or to dissolve it. And when it dissolves the aurum fulminans, it does not hold it long suspended, but deposits it in its pure and metallic form.*

Other metals also can be employed to precipitate the gold: and there are several that precipitate it, although they are themselves combined with an acid. They produce this effect in consequence of the strong elective attraction which they have for the muriatic acid, and for the oxygen, both of which they separate from the gold.

The metallic solutions which have been applied to this purpose, are,

The solution of sulphat of iron;

The solution of nitrate of quicksilver;...and

The solution of tin in the nitro-muriatic solvent.

It is easy to understand how the two first produce their effect. And I shall only observe, that the precipitate by the mercurial nitrate is very readily dissolved by mercury. It is useful in this way for gilding upon glass or porcelain. But the precipitate by martial vitriol is far preferable, affording a much richer colour, seemingly owing to a small quantity of copper contained in the vitriol.

The effect of the solution of tin depends on this particular circumstance, that though the tin be already combined with a quantity of the muriatic acid in the nitro-muriatic solvent,

* Since we see the æther separate the gold from its solvent in the metallic state, we can scarcely expect any action of æther on metallic gold. Experiments on this metal being so expensive, they have not been made on large enough quantities for observing with accuracy what changes are induced on the æther, in this experiment. The phenomena accompanying the separation of gold by aromatic oils, give considerable information, and very conformable to Dr. Black's opinion. These oils are inspissated in the same manner as by the contact of vital air. We should expect a similar change on the æther to what pure vital air produces on it, forasmuch as it deoxydates the gold: and we should expect some combination of the æther with the acid. If we observe the æther changed as it would be by so much aqua regia, we should ascribe the separation of the gold entirely to the attraction of the æther for the acid. If the change be different, we should ascribe it, at least in part, to its attraction for pure oxygen. The phenomena give indications of both. The æther mixes with the acid only to a certain degree: and the acid, thus combined with æther, has no further action on metallic gold... EDITOR.

and also with a quantity of oxygen, it is not saturated with either of them. It has still an attraction for more, and therefore takes them from the gold.

The precipitate of gold, thus obtained, is the most remarkable of any by its fine and rich colour. The colour is so deep, that this experiment is a way to discover the smallest quantity of gold in a solution. And a red or purple appears to be the colour natural to gold, when very subtilely divided,...by electrical fire, for example, or other means. The purple stain given by the solution of gold to animal and vegetable substances, is another example.

This precipitate is valued, and very much used, as a fine purple for enamel colours. It has the advantage of enduring the fire without undergoing any change of its colour, to which many other enamel colours are liable.

I have already described the process for preparing the solution of tin that is employed in the preparation of this purple precipitate of gold, known by the name of the *purple of Cassius*. It was described as a solution of tin in aqua regia, and with every precaution to have the metal as slightly calcined as possible, and the acid completely saturated with tin. I shall now take notice of the circumstances which must be attended to, in order have the solution of gold in the most proper state. It is found often to fail, when the gold is dissolved in a mixture of the two acids; seldom, when the aqua regia is made by adding common salt, very pure, to nitric acid; and scarcely ever, if sal ammoniac be employed. The greatest nicety lies in the degree of dilution of the solution of tin. As this depends on the oxydation of the tin, it is best to determine it by trial. Having diluted the tin solution with eighty times its bulk of water, put three or four portions of it into glasses, and dilute each of them differently; then, dipping a glass rod to a certain depth in the solution of gold, rinse it in one of the glasses; do the same to another; to a third, &c. Then notice in which glass the precipitate has the richest and most beautiful tint of purple, and dilute the whole according to that standard. The precipitate both forms and falls down very slowly, being in some degree gelatinous. By long rest, however, it all

falls down: and then the clear liquor may be decanted off, and the precipitate cleared by edulcoration and a filtre.

Orschall, one of the celebrated older chemists, says, that he obtained a very fine precipitate by means of the fuming liquor of Libavius; also by means of a solution of tin with corrosive sublimate made by deliquescence; and a still more beautiful precipitate than what tin can produce, by means of mercury dissolved in aqua regia.

But Orschall knew only the preparation of the enamel colour, which has great body, as the painters call it, but little transparency. The transparent red and purple is of great value for *staining* glass. It is made by diluting the purple of Cassius with pure crystal or glass. This is a preparation still more capricious and uncertain. Frequently the glass has no colour whatever. But if a rod of such glass be made red hot, and held in a smoky flame of wood, it becomes purple in an instant. But this is merely superficial: and if the glass is to be formed into any other shape, the colour vanishes in the working, and it again requires the assistance of the oily flame. This is called *Few's glass*.

Neuman says, and Dr. Lewis confirms it in his notes, that the preparation of the purple precipitate never fails, if made by simply putting pure tin into the solution of gold greatly diluted.

Margraaf has published, in the Mem. Acad. Berlin, 1779, a series of most judicious experiments for determining the best process for this valuable precipitate; and I refer you to him for farther information. I must observe, however, that our artists call the purple of Cassius a tender colour; because a considerable heat makes it transparent, and therefore of a different tint, according to its thickness on the ware. It does not suit enamel, therefore, so well as staining of glass; because the other colours by copper, cobalt, &c. require much higher heats in order to bring them to their full colour; and are therefore melted several times in crucibles before they are ground to powder for the painting in enamel. Even then, they require more heat than the purple of Cassius bears without risk of losing its body.

Inflammable Substances with Gold.

Sulphur, which unites so readily with most of the other metals, cannot be combined with gold. But if we first join the sulphur with a fixed alkali, equal in quantity to the sulphur, the sulphuret thus formed, if applied to gold in thin plates or leaves, and in the way of fusion, very readily combines with it, or dissolves it. And if the compound be immediately poured out of the crucible, and soon after dissolved in water, a part of the gold will be dissolved along with the sulphuret, while the rest remains in the state of a very subtile powder. Dr. Stahl had a notion that this process, which is certainly an ancient one, was known to Moses, and was practised by him when he made the children of Israel drink the golden calf. It is indeed true that this potion is extremely nauseous, having a pungent bitterness not to be felt in the similar preparations of other metals.

The effects of alcohol, æther, and aromatic oils, on the solution of gold, have been mentioned already.

The only other inflammable substance remarkable for its effects on gold, is phosphorus, the powers of which, with respect to metals in general, have been ably investigated by M. Pelletier. When thrown into melted gold, a certain quantity unites with the metal, forming a phosphoret of gold, which is more fusible than the gold by itself. But if the compound remain in the fire, and air be admitted, the phosphorus is gradually burnt, and changed into acid, which separates from the gold.

Relation of Gold to other Metals.

Gold may be mixed with any of the other metals; and it is by the admixture of some of these that it is made to appear of those different colours which are seen in the inlaid gold of trinkets and toys. Copper inclines the colour of gold to red; silver makes it pale; and if the silver be one to four of the gold, a greenish hue is produced. Pure gold is a full yellow. The Venetian chequin has the richest colour of any gold; and the art of giving it this high colour is kept a secret in the mint of Venice. I made a piece of fine gold acquire the same

colour, (but it was only superficial) by keeping it long red hot under charcoal dust.

In its pure state, it is thought too soft and flexible for making toys and utensils, or coin. And the general practice is to add some of the other metals, which give it more stiffness and hardness. This addition is named the *alloy* of the gold. It is commonly silver and copper, of which one part is added to eleven of the pure gold, for the standard of Great Britain. One pound avoirdupois of standard gold, is worth $56\frac{11}{12}\frac{2}{3}$ /. Sterling.....1000/. Sterling weighs (avoirdup.) 7 pound $9\frac{1}{16}\frac{4}{16}\frac{5}{16}$ ounces.

In speaking of the quantity of alloy in gold, the term carat has been used. A carat is the twenty-fourth part of a mass of gold, great or small: And each carat is subdivided into twenty-four parts, denominated grains. Our coin then is of twenty-two carats.

The relation of gold to quicksilver, and the art of gilding metals founded on it, has been noticed already in treating of quicksilver.

Other methods are practised for gilding, in which mercury has no share. As almost all the metals precipitate gold from its solution, and precipitate it in the metallic state, any of these metals, put into a solution of gold, will be immediately covered with the deposited gold. This covering will rarely be made to adhere; because the surface of metal which we would gild is oxydated. But, by methods resembling what I described for whitening or tinning pins, the pure metals may be applied to each other; and then the burnisher makes them adhere, spreading, at the same time, the gold over the parts where none was deposited. The best of these processes are kept secret by the possessors. There is a family at Nuremberg, which has preserved one a secret for upwards of two centuries; and their gilding, even on the most common work, has a solidity and richness of colour that is not equalled by any other artists in Europe.

There is a still more simple way of slight gilding. Linen rags, soaked in the solution of gold, are burned to ashes. A smooth cork, superficially charred, is wetted and dipped among these ashes: and then rubbed carefully over the piece to be

gilded. The reduced gold among the ashes is thus pressed on the work so as to adhere ; and by going over it several times, it is completely covered ; and bears to be rubbed very hard with a fine linen rag, strained on a bit of cork. This gives the work a fine polish, and great brilliancy : and is pretty durable on the inside of cups, and other situations which do not require often scouring.

You must have often heard the terms of *tried gold*, and of the *trials of gold*. These are trials, or processes, by which we can assure ourselves whether a metal which resembles gold be gold or not ; and if it be gold, whether it is pure or alloyed : and if alloyed, what proportions of pure gold and of alloy it contains. The operations which have been long in common use for these purposes are five in number :

1. The use of the touchstone, (*lapis lydius*.)
2. Cementation.
3. Refinement with antimony.
4. Cupellation with lead.
5. Parting, or the depart.

1st, The touchstone shews whether a metal be gold or not ; and if gold, of what fineness nearly, by needles. The piece of gold is rubbed on a black stone of the jasper kind, having a fine siliceous grain and argillaceous cement. Some of the hardest of the antique, or of Wedgewood's black pottery, answers the same purpose. The metal leaves a trace on the stone. A set of touch needles are made, consisting of gold, with various proportions of alloy. The tryer makes a stroke with one of the needles close by the one made by the metal under trial ; and changes the needle, till he has got a stroke exactly like it. Thus he judges of the proportion. To be more exact, he draws over both strokes a pencil dipped in aqua regia. This dissolves all the gold, and leaves the silver. The proportion of alloy is thus more clearly seen.

This method will not detect adulteration, when the piece has been cemented in the manufacturing. This makes it fine superficially, though internally base. If the stroke shew very fine gold, we may be almost certain that the piece has been cemented.

2d, Cementation is seldom used, as requiring repetitions. Although a small quantity of base metal, concealed in a large

quantity of gold, is thereby shielded from the acids acting in the humid way, they cannot resist their action in dry burning vapours. Therefore adulterated gold, being first laminated, is stratified with a mixture of calcined martial vitriol and nitre, or common salt, (not both,) and a quantity of powdered brick, and exposed to a cementing heat for some hours. The piece is taken out, melted, and again laminated, and again cemented,.... "seven times tried in the furnace." By each operation, part of the base metal is destroyed.

3d, Crude antimony is more frequently used. It is better than pure sulphur; because pure sulphur is too volatile, and metallic antimony washes down the gold. But the crude antimony absorbs and scorifies all the baser metals.

4th, Cupellation is still more frequent as a means of purging the gold of copper, and all baser metals: and an addition of silver facilitates this operation, and makes it more perfect. If there be no silver in the mixed metal, the gold retains, in the end of the cupellation, a small portion of copper, which it defends from the action of the lead and heat.

5th, But after thus cupelling the gold with this admixture of silver, we must have recourse to the operation of parting, to have the gold pure. This parting is the separation of the gold from the silver, performed by aquafortis, or aqua regia. Aquafortis is commonly employed: and the use of it is quite simple and easy. I shewed you an example when I dissolved silver in aquafortis. The small portion of gold which the silver contained, remains undissolved, and retains its shape: and it needs only to be boiled with a little fresh aquafortis to make it quite pure; for if this be not done, it retains some of the silver. In order to enable the aquafortis to act properly on this metallic mixture, there must be at least twice as much of the silver as of the gold, and the aquafortis must be sufficiently strong. It is also usual to reduce the metallic mass into small grains and fragments, by melting it, and pouring it into cold water. This is done to increase the surface of contact between it and the aquafortis. Or if we have but a small quantity of it, as in assaying, it is rolled out into a thin plate, between two small steel rollers: and this plate is twisted into a spiral.

When the mixture contains more gold than silver, in the proportion of two to one at least, we may use aqua regia to separate these two metals. It will dissolve the gold, and leave the silver at the bottom, in the form of muriatic silver. The solution of gold being then carefully separated from the silver, the gold is commonly precipitated with solution of quicksilver in aquafortis. This occasions the gold to fall in the form of a dark-coloured powder, which, after it is well washed, is easily melted into a mass with a little borax.

There is another method of refining gold, which is now commonly practised, when the gold contains a small quantity of alloy only, and that of such a nature as to deprive it of toughness and malleability, such as iron, tin, brass, or any of the semi-metals. The method I mean is, to melt it, and add to it repeatedly, while in fusion, small doses of the corrosive muriatic of quicksilver, until it is fine or tough. This corrodes the alloy, and soon brings it to the surface as a scoria, where it works off.

When a small proportion only of gold is contained in a metallic mixture, the processes for extracting it are often different from those already described. In general it is separated from all other metals, except copper, in the same manner as silver is extracted from them. But when the gold is contained in copper, it cannot be extracted by the same operation which serves for extracting silver from copper; which is the addition of lead and the eliquation of the lead. The gold is not brought out by this process. It has a stronger attraction for copper than for lead. A successful method was, however, discovered in Germany, which was very profitable to those who practised it first: and it still continues to be the best method for extracting a little gold from metallic copper. It is done by melting the copper with sulphur and lead at the same time. The copper unites with the sulphur, and is thereby disposed to quit the gold to the lead. The process is described in Lewis's *Commercium*, and Cramer's book on *Assaying*.

A somewhat similar process, by which gold was extricated from silver that contained but a small quantity of it, had long been practised before the chemists thought of employing it in the

case of copper. Cramer describes this process with silver very particularly.

Natural History of Gold.

It must be acknowledged, that gold, though it be not the most useful of the metals, has some admirable qualities. Its rich colour and lustre, which are never obscured with tarnish or rust, and its astonishing extensibility, which enables us to employ it in the embellishment of the works of art at a very moderate expence, are one foundation for the value that is set on it. The principal cause, however, of the high price of gold, is the difficulty of procuring it. And yet there is more of it produced by nature than is commonly imagined. But it is generally dispersed through such immense quantities of other matter, that it cannot be collected without great labour and expence.

The Spanish and Portuguese parts of America, and some parts of India and Africa, afford the largest quantities of gold. Amazing reports have been published of the abundance of this metal in some of the Spanish possessions in America; but these reports are published in late accounts of some newly discovered places where gold has been found, and the accounts of such new discoveries are commonly amplified.*

* Some parts of the new kingdom of Grenada (which is a high inland country east of the Andes, and in the north end of South America) are rich in gold, which is all wash-gold. On a rising ground near Pamplona, single labourers have collected in a day what was equal in value to 1000 pesos, or to 225l. Sterling = 57 ounces 4 drachms 42 grains. A late governor of Santa Fe brought with him to Spain a lump of virgin gold estimated to be worth 7040l. Sterling. (The weight of it must have been about 189 ounces, or 23 merks and 5 ounces, even supposing it gold equal in purity to English standard.)

At Cineguilla, in the province of Sonora, the Spaniards found a plain fourteen leagues in extent, in which they found wash-gold at the depth of only sixteen inches, the grains of such a size that some of them weighed nine merks, and in such quantities, that in a short time, with a few labourers, they collected 1000 merks of gold in grains, (equal in value to 31,219l. 10s. Sterling) even without taking time to wash the earth that had been dug, which appeared to be so rich, that persons of skill computed that it might yield gold to the value of a million of pesos; which is equal to 225,000l. Sterling. In one place, called the *Mine Tecorata*, in Cinalod, they

Wherever gold occurs, it is found much more commonly in its metallic state, and nearly pure, than in the state of an ore. This is probably a consequence of its having no attraction for sulphur, and very little for arsenic, and of its resisting the action of the mineral acids. I believe all the gold collected in America and Africa is found metallic, and uncombined with the common mineralizing substances. But in Europe there are some mines which yield *ores*, containing a small quantity of it. These ores are not, properly speaking, ores of gold. They are ores of other metals; but the small quantity of gold which they contain along with the other metals, occasions their being considered as ores of gold. In Hungary, a considerable quantity is extracted from some ores of quicksilver, and from a pyrites of iron and sulphur. In the Hartz forest in Germany, there is an ore which affords zinc, and lead, and silver, and a small quantity of gold. And both there and in other parts of Europe, there is found in some places a black sand, like small grained gunpowder, which is an ore of iron, and contains some gold.

In some of those ores, it is either intimately combined and mineralized with the materials of which the ore is principally composed; or, if it be in its metallic and pure state, it is in such minute atoms, that it is not discoverable by vision until it be collected together by itself. There is reason, however, to believe that it is always in this state. When the Hungarian pyrites is dissolved with aquafortis, it is said that the gold is left by that acid in the form of minute atoms, and fine films, which are in a metallic state. And as this pyrites varies much in the quantity of gold it contains, and some of it does not contain any, there is reason to believe that all the gold in it, is metallic and pure, and only dispersed through it in very minute films not mineralized. However that be, by far the greater part of the gold which is collected in different quarters of the world, is found free from mineralizing substances, and nearly pure; or contains only some silver, and sometimes a little iron or copper. And this virgin gold, as it is, called, is found in two states or

found a grain of gold 22 carats fine, which weighed 16 marks 4 ounces 4 ochavas. It is now deposited in the royal cabinet at Madrid. This grain is worth $496\frac{1}{12}\frac{6}{3}$ l. Sterling.

conditions ; that is, either in the solid veins of the mountains, in which it seems to have been originally formed, or deposited by nature like other metals, and from which it is in this case cut out by mining in the usual manner,...or mixed with the loose soil and rubbish, on the surface of such mountains, or in the plains that are below them, or near them.

In the first of these states (I mean in the original veins) it is found but rarely. By far the greatest part of it is collected from among loose soil, and gravel, and sands,...especially from the gravel and sand of brooks in some mountainous countries, and from the soil which is near to such brooks. Also in the soil of plains formed by the rivers into which such brooks empty themselves, and in the sands of such rivers.

And when we examine the gold found in these different places, we find reason to be satisfied, that it is brought down from the mountains by the gradual and long continued action of water and the atmosphere on the materials through which it is dispersed. The proofs of this are, that the nearer to the mountains it is found, the grains of it are in general so much the larger, and the rougher or less worn;...while such of it as is found at a distance from the mountains, or from the highest parts of the country, always consist of grains smaller in their size, and evidently smoothed on their surface, and worn by the attrition they have sustained from the sand and gravel, during the great length of time required for their being brought down so far. You have examples of this general fact in the gold which is found in the sands of some of the rivers of France, of which an elegant and entertaining account is given by Mr. Reaumur in the memoirs of the academy for the year 1718.

We have also an example of the same fact in Scotland. Gold is found at Lead Hills, and in a district there called Etrick Forest. The gold is all in the form of small grains, dispersed through the gravel of the brooks, and in the soil that is near them. It was thought an object of value a long time ago, when gold was dearer than now : and great numbers of hands were employed in collecting it. From some registers, it appears that in one year 48000*l.* sterling value of this gold was coined in the Scotch mint. The grains are in general the larger and rougher,

the higher up the country they are found. The farther we descend, they are more dispersed and of a smaller size, and more worn and smoothed. The same thing also was observed by Baron Born in Hungary and Bohemia. This points out very evidently from whence this gold comes, which is thus found in the soil, gravel, or sand, of these particular districts or rivers. And there cannot be a doubt that the gold which has been lately found in Ireland has had the same origin. In those hills that confine the valley and the brook around which it is found, there are certainly mineral veins containing gold. And they cannot be far distant, if I may judge from a specimen I saw of the gold grains. They are so rough, and have so little appearance of being worn, that they cannot be far removed from their original veins.

From the manner in which gold is deposited in sands, &c. it will often appear to be accumulated in particular soils and sands into much richer collections than what can be found in the veins themselves from which it descended. The deposits of this kind in some of the lately explored districts of Spanish America, as they have been described by the visitors, exceed all belief. According to some of them, a man can gather to the value of 200*l.* sterling in a day, by washing the common soil in some of the valleys. The soil in which it is found must be considered as the relics of the rubbish of mountains, deposited upon mountains which have been demolished and washed away. One of the strong proofs of the great antiquity of this globe is the considerable quantity of gold found in the soils and sands of some districts. It is a clear proof of an operation or process which must have required a length of time that is far too great for our comprehension.

The size of the gold grains is extremely various. The greatest part of them are very small; some as large as the seeds of apples, and some much larger. The grains of the Irish gold are uncommonly large. Reaumur reports that a piece was shewn to the French Academy, said to weigh 56 marks, or 448 ounces. Feuillee says he saw one in the cabinet of Antonio Portocarrero, which weighed upwards of 66 marks. Both pieces were assayed, and found of different fineness in different

parts of the mass. One was of $23\frac{1}{2}$ carats, 23, 22. The other of 22, 21, $17\frac{1}{2}$. It is, however, rare to find pieces one ounce in weight. The largest in the British Museum is only 15 penny-weights. In Chili 5000 pound weight of the richest ore yields only 12 ounces, which is not quite one grain per pound. Ore is wrought there without loss, if it contain one-sixth of this. On the coast of Guinea, a man can gain seven shillings sterling per day by washing the common sands on the river banks. From half a ton of the richest part of the soil at Lead Hills, washed under my inspection, the produce of gold was $11\frac{1}{2}$ grains.

In this manner, therefore, is gold separated from its original matrix, and collected in certain places by nature. It remains to describe how man provides this metal for himself, by imitating more or less, or by completing this operation. This description will be extremely short; because the account already given of the peculiar properties of this metal, and of the state of its ores, and of the operations in metallurgy, requires nothing but general indications of what is to be done.

The first operation is an imitation of nature. The native gold being in small grains, either among the sands and gravel, or perhaps bedded in the stony matters, the whole is pounded by mills: and then the sand so formed is agitated with much water in buckets, or baskets, or cisterns, by stirring it with rakes; and by a sleight of hand, acquired by practice, the lighter sand, occupying the upper part of the water, is dashed over the brim. The gold particles remain with the heavier sand. This is also dashed over, after stirring: but it falls on a long sloping table covered with rug. The stream carries the lighter particles over all the rug, and off the table. The heavier matter sticks in the rug, and a few grains of gold are found towards the upper end of it. These are shaken or washed off from time to time, and added to the heaviest particles which remained in the baskets or cisterns. Thus all the grains are at last collected; but along with them much baser metals, or their ores, which are also very heavy.

The next operation is roasting this dust, to drive off sulphurous and arsenical matter which is combined with the base metals.

The whole is now triturated in tubs with a quantity of mercury, which dissolves the gold and silver, and forms an amalgam. This operation is expedited by adding a quantity of water and of common salt. The water facilitates the labour, and also assists the mercury in throwing out the base metals. The common salt decomposes the vitriolic salts which were produced by the roasting and burning of the sulphur.

In the next place, the greatest part of the mercury is separated, nearly pure, by squeezing the whole thin paste through porous leather. The firm mass which remains contains all the gold and silver, and a good deal of mercury. The last is got off by distillation.

The last operation is the separation of the silver from the gold, and the refinement of both, by such of the processes already described as is suited to the proportion of the two metals, and the impurities with which they may be tainted.

And when the gold is found combined with the ores of other metals, that is, when ores of other metals are treated for the gold which they contain, processes must be employed for scorifying these metals, in one way or another, whether by sulphurating them, or by lead till the gold and silver are left alone, to be treated as now mentioned. For a more particular account I must refer you to Agricola, Schlutter, and Born.

GENUS XV.....PLATINA, OR PLATINUM.

THIS metal was first brought to England in the year 1749 or 1750, by Dr. Brownrigg, who presented it to the Royal Society. He had received it from Mr. Charles Wood, assay master in Jamaica, who told him it came from some of the Spanish provinces in America; and that it had several of the qualities of gold, in consequence of which it was very difficult to separate it from that metal; and that the name given to it by the Spaniards was *platina* or *platina del Pinto*, and *Juan blanco*. Platina is the diminutive of *Plata*, silver: and Pinto is supposed to be the name of a mountain, or river, or person.

Soon after it was known in England, specimens of it were brought to other parts of Europe : and the attention of many chemists was engaged by it. They made many experiments, and wrote dissertations on this metal; of which we have examples in those published by Mr. Lewis in the *Philosophical Transactions* for the years 1754 and 1755, and in his *Commercium Philosophico-technicum*; Mr. Scheffer's paper in the *Transactions of the Swedish Academy* for the year 1752; Mr. Margraaf's dissertation in the *Memoirs of the Royal Academy of Berlin* for the year 1757, printed in 1759; and a memoir by Macquer and Beaumé, in the *Memoirs of the Royal Academy of Sciences at Paris*, for the year 1758, printed in the year 1763; and many more since that time.

Platinum is brought from America, in loose grains of the size of coarse sand, most of them smooth on their edges and sides, having the metallic opacity and lustre, and a dingy white colour, not brighter than that of iron; and they are all attracted, more or less, by the magnet. But, intermixed with these grains of the platinum, there are generally others of a smaller size, which are plainly iron ore, or iron sand. In some specimens, also, a few small grains of gold are found; and Mr. Lewis also observed a little quicksilver adhering to the gold. Mr. Lewis therefore conjectured that the platinum is obtained in washing some soils or sands for gold.

By the numerous experiments that have been made with this metal, it is now ascertained, that in these grains it is intimately and strongly united with about one-third of its weight of iron, and that it is not easily refined. When rendered free from all admixture, it has a whiter colour; and is the heaviest metallic substance known at present. Refined gold is little more than nineteen times as heavy as water. But refined platinum is twenty-two times the weight of that fluid. Even in its natural state, the specific gravity of it is very uncommon. It is sixteen or seventeen, or, when the picked grains are tried, eighteen times as heavy as water.

When refined, it is also very malleable and ductile; although in its natural impure state it has but a very small degree of malleability.

One of the most extraordinary qualities of this metal is its resistance to the action of heat, when applied with the purpose of melting it, without the addition of other metals. Macquer and Beaumé kept it in the greatest heat of a porcelain kiln, and in a glass-house furnace, without making any change on it. The fusion of it was at last accomplished, however, by Mr. Macquer, by employing the intense heat of Vilette's speculum, and the great lense belonging to the Academy, both of which exceed the best furnaces, in the intensity of their heat. Mr. Lavoisier also succeeded with the blow-pipe, and with other fuel, by employing oxygen gas.

It possesses another singular property that of compacting or welding, by the blows of a hammer, in the same manner as iron: and thus it may be brought from the spongy state in which it is left by the processes for refining, to the utmost density and compactness.

In the further prosecution of these experiments with heat, and in those that were made with solvents, platina was found to have the same degree of power to retain its metallic form and purity, and the same disposition to recover them when lost, that silver and gold have.

It suffers no change from the action of air and heat; nor is it affected by nitre in the fire. Crude platinum, or the grains in their natural state, are corroded and calcined by melted nitre: but it is evidently the iron which they contain that is attacked by the nitre, and, when the platinum is once completely refined, the nitre has no power to calcine it. This metal also resists the calcining powers of heat and air, in cupellation with lead. It not only remains unchanged, like silver and gold, while the lead is changed into litharge, but defends a portion of the lead from being calcined equal to about one-fifth of its own weight.

Thus, by its resistance to the action of oxygen, it bears a resemblance to silver and gold. But, upon the whole, it agrees more with gold than with silver.

It is similar to gold by resisting the action of pure sulphur, and consequently of the sulphuret of antimony, which can therefore be employed to assist in refining it from iron. But the metallic part of the antimony adheres to it afterwards very strongly.

But, though the platinum cannot be united with pure sulphur, it can, like gold, be dissolved by the melted sulphuret of potash, though not so easily.

None of the acids, in their ordinary state, act on platina, in whatever manner they are applied, whether in their common form, or that of hot and dry vapours, by cementation. Like gold, it can only be dissolved by oxygenated muriatic acid, or by aqua regia; commonly by aqua regia composed of equal parts of aquafortis and muriatic acid. Such an aqua regia will dissolve about one-twelfth, or one sixteenth of its weight by digestion, or one-eighth by cohobation, according to Lewis. It has little causticity: and it stains the skin an indelible brown.

When this solution is evaporated for crystallization, it affords small crystals like grains of sand, of a deep yellow or red colour, and sometimes opaque. When they are washed and dried, they require more boiling water to dissolve them than five-hundred times their weight. The solution is yellow, and deposits a pale-coloured and very light sediment, supposed by Bergmann to be iron.

The solution of platina shews also very particular properties, when we add to it alkaline salts, in order to precipitate the platina. Professor Bergmann made many accurate experiments with it in this way; and has been much more successful than Mr. Lewis in discovering the manner in which alkalis act on the solution of platinum. You may see his account of these experiments in his dissertation on this metal.

I shall at present mention only the most remarkable properties by which this solution differs from that of gold.

1st, One remarkable difference is observed in the effect of sal ammoniac on it. The solution of sal ammoniac, or muriat of ammonia, in water, produces no perceptible effect on the solution of gold. But when a saturated solution of this salt is added to the solution of platinum, an orange-coloured precipitate is instantly formed, which experiments have shewn to be the platinum, or a part of it, combined with a small portion of the ammoniacal muriat. This precipitate is still dissolvable, though with difficulty, in a large quantity of water.

2*d*, We find a difference between the solution of platinum, and that of gold, when we mix them with alcohol, æther, or the aromatic oils. These fluids make the gold separate sooner or later from the acid in its bright metallic form. But when they are added to the solution of platinum, no such effect is ever produced.

3*d*, This solution also differs from the solution of gold, by the manner in which it is affected by other metals, or their solutions, particularly by the solution of the sulphat of iron, and the solution of tin. Both of these precipitate gold : and the solution of tin, in particular, precipitates in the form of the fine purple for enamels. But neither has any effect upon the solution of platinum. These differences are the foundation of the methods by which these two metals can be completely and exactly separated from one another.

One of the points to which Mr. Lewis was most attentive in studying the nature of this metal, was, to learn the consequences of mixing it with other metallic substances. As it was not fusible alone, the only manner in which it could be applied to use, appeared to be by mixing it with other metals, which might have the power to dissolve it in the fire, and to unite with it, so as to form useful mixtures. But he obtained no products that promise to be useful, except with copper, a mixture of moderate toughness, extremely hard, and which does not tarnish ; and with iron, a mixture of extraordinary strength and hardness.

Such mixtures, however, afford us the only means of manufacturing it. They render it fusible : and thus it may be moulded. The other metals may then be abstracted, by various processes, leaving it pure, but porous or spongy. In this state it may be compacted and rendered perfectly solid, by forging, and thus manufactured into any shape. By such processes platinum becomes one of the most valuable metals that we know.

It unites readily with bismuth ; most easily of all with tin, flowing very thin ; also with lead ; and forms a metal which will not scorify, nor be absorbed by the cupel.

Dr. Lewis's principal purpose, by these mixtures, was to learn the consequences of mixing platinum with gold, in different proportions.

The reason of his having this object in view was, that the platinum was considered as capable of being mixed with gold, so as to commit great frauds in traffic, without the possibility of detection by the common trials of the purity of gold, or of the quantity and nature of its alloy.

He therefore mixed it by fusion with gold, in many different proportions. But, in general, it debased the colour and the malleability of the gold so much, even when it was only one twenty-fourth part of it, that he concluded that no great frauds could ever be committed by employing the grains of platinum for the adulteration of gold. And methods are now well known, by which we can easily refine gold that has been adulterated with platinum. We can easily therefore detect such frauds, and learn the amount of them. The best of these methods is the one invented by Mr. Scheffer of Sweden. The adulterated gold must be dissolved with its usual solvent, the nitro-muriatic. And we must then add a solution of the sulphat of iron. Every atom of the gold is quickly precipitated, while every atom of the platinum remains dissolved. We must then wait until the gold has completely subsided: and afterwards, pouring off the liquor, we must wash the precipitated gold with repeated waters, and great care to avoid loss. And lastly, being dried, it is easily melted into a mass with a little borax and nitre.

It may be remarked, however, with respect to Mr. Lewis's experiments on the mixtures of platinum with gold, that they are imperfect on this account; he made use of the platinum in its native state; in which state it is always mixed with iron: and the gold which he alloyed with platinum was therefore alloyed with iron at the same time. Later experiments have shewn that the quantity of iron in native platinum amounts to one-third of its weight. And these metals are so strongly and closely combined together, that it is only of late that methods have been discovered for separating the iron.

The most successful methods that I have heard of are these:

One way is, to dissolve the grains in the nitro-muriatic solvent, and precipitate the iron from the solution, with

Prussian alkali. The prussiat of soda is the best for this purpose. This is a most effectual precipitant of iron; and produces no effect on the dissolved platina, provided no more be used than enough to precipitate the iron. The solution of platina, thus freed from the iron, may next be evaporated to dryness: and the dry matter, exposed to a violent heat, gives the platina pure.

A second way is, after dissolving the grains of platina, to precipitate the solution with a solution of sal ammoniac, and then expose the orange-coloured precipitate to a violent heat, by which the salts that adhere to it are evaporated, and along with them any small portion of the iron which may adhere to the precipitate.

A third method which has been practised with success, and is the cheapest, is to refine it with arsenic. Platina, white arsenic, (or rather the arseniat of potash) and tartar, in equal quantities, are melted by a violent heat, and form a very brittle white mixture, of metallic lustre. This is exposed to heat and air under a muffle, which dissipate the arsenic and the iron in vapour, leaving the platina pure, to be compacted by the hammer.

Fourthly, Mr. Macquer found that it could be refined with lead by cupellation. But a most intense and long continued heat is required to evaporate the last portion of the lead from it. This method can only be applied in the refinement of a very small quantity of it. From a larger quantity it would be impossible to evaporate the last of the lead. (*See Lewis's Commercio Philosophico-technicum.*)

And lastly, some of Mr. Pelletier's experiments with phosphorus point out another method of refining it, which he says, is easily practicable. He heated the grains of platinum in a crucible, and then threw in some bits of phosphorus. The phosphorus instantly penetrated the grains, and formed a fusible metallic compound,....a phosphoret of platinum. If this compound be exposed to a strong heat for some time, the phosphorus is gradually burnt, and with it the iron, which forms a scoria or slag with the melted acid of the phosphorus. The platinum is thus purified, but is no longer fusible: and it remains very spongy, with the scoria adhering to it, partly on its surface, and partly in its pores. He therefore gives it

a strong heat, and suddenly compresses it in that state with the blows of a very heavy hammer, such as is employed in the process of refining iron. This effectually compacts the platinum, forces the scoria out of its pores, and makes the parts of it unite together.*

This method of compacting platinum, and uniting the parts of it by percussion, when strongly heated, was first suggested by Mr. Beaumé: and it must be employed in every case in which this metal is refined. We cannot unite the parts of it by fusion with any heat that furnaces can give.

When by these processes platina has been purified from all admixture, it has the colour of pure tin; is very malleable, growing rigid by the hammering; but may be softened by annealing. In this state, its density or specific gravity is from 20 to 22.

It is now to be hoped that this metal will be imported more freely into Europe; and that the mining grounds in America in which it is found will be opened again. The Spanish government at first prohibited the collection and importation of it, from apprehensions that it would embarrass their commerce in gold, by giving opportunity for frauds not easily detected. But there is no reason now for such apprehensions and precautions, since methods have been discovered for detecting the smallest quantity of platinum mixed with gold, and for easily separating these metals from one another. And were the properties of platinum more fully investigated, methods for working it easily into utensils might be discovered: and then it might justly be considered as one of the most useful of the metallic substances. Its resistance to the action of fire, together with its incorruptibility and cleanliness, would render it valuable for domestic purposes. The chemists already employ it on account of these qualities in some of their nice experiments and processes. (*See Note 66. at the end of the Volume.*)

* Would not cementation with charcoal and bone-ashes, or the stone mentioned in page 268, accomplish this purpose, without the expence of preparing the phosphorus, ... and thus afford a very easy method of manufacturing this useful metal? EN D OF.

CLASS V.

OF WATERS.

IN former parts of this course, we have had already opportunities to notice the important and numerous uses of water in the system of the universe.

It is said of some of the ancient philosophers, that they supposed all things derived their origin from water. And it is true that the existence of all the numerous tribes of vegetables and animals depends upon it. And when we examine the materials of which they are composed, water is always the principal part. But must we also suppose that water has given origin to the more solid and durable parts of this globe, the various earths and stones, the rocks and minerals of which the mountains and land are composed? Have all these been produced from water?

Whatever opinion we may form of the origin of these, it is at least certain, that water has been the agent employed to give the regular arrangement in which many of them are found.

The appearance of numerous relics of sea productions, and other traces of this fluid, are so frequent in the strata of which this globe, so far as we can observe, is principally composed, that there is no room to doubt that the materials of these strata have been arranged in that manner by the sea. But some have concluded from these phenomena, and some other facts, that water has even furnished the matter of the earthy and stony bodies,...that water is actually convertible into earth.

The first author who has mentioned the convertibility of water into earth is Mr. Boyle. He writes, that a friend of his was in possession of three-fourths of an ounce of earth, produced from one ounce of water by the action of a long continued heat. And he relates some experiments made by himself, which convinced him that earth could be produced from the purest water by heat.

I repeated Mr. Boyle's experiment, by boiling and circulating boiling water a long time in a glass vessel luted up quite close: and I saw the appearance by which he was deceived.

Godfrey, the descendant of Mr. Boyle's assistant, thought he converted water into earth by triture. Wallerius also relates, in the Swedish transactions, experiments in which, by triture, or agitation, or both, a quantity of siliceous matter was obtained from water. And Mr. Margraaf obtained it by distillation.

Lavoisier's opinion is, that the earthy matter produced by boiling of water in glass vessels, is a part of the glass corroded by muriatic acid, present in all waters.

My opinion is, that this matter is a part of the glass corroded or penetrated by the water itself, which alone has the power to penetrate it, and even to dissolve it, by length of time and assistance of heat. This explains the form and appearance of this matter, which is always in fine minute and thin scales, and also the change observed in the water, when the experiment has been continued a long time. It is said to boil more like oil than like water. This proceeds from its holding a small portion of the glass, or of the alkali of the glass, perfectly dissolved. By my observations on the Geyser springs of Iceland I found that water held siliceous earth in solution.

Another opinion, however, has been lately formed with regard to it, which is of greater consequence, as it enables us to understand and explain a number of chemical facts. The opinion I mean is that which we have already adopted and applied in former parts of this course; that water is not a simple elementary substance, but a compound.

This idea of the nature of water was suggested by Mr. Watt. (*Phil. Trans.* 1784.) Mr. Cavendish, however,

was the first who gave it solid foundation and credibility, by his accurate examination of the consequences of setting fire to a mixture of hydrogen gas and oxygen gas, in a vessel in which they were confined. Mr. Lavoisier and other French chemists, seeing the vast importance of this experiment in their system, immediately repeated it, with much larger quantities of the materials, and with an excellent apparatus and the most scrupulous accuracy. They added several other experiments, which concur to establish the opinion of the compounded nature of water. They also soon perceived and pointed out the important improvements which might be deduced from this discovery in the explication of many chemical facts, which were thus set in the clearest light. And since that time, the last finishing, we may say, has been given to this happy chain of experiments: and the compounded nature of water has been still further illustrated, by the capital experiment of the Dutch society of chemical philosophers, who resolved water into its two constituent parts, without making any addition to it whatever, but the matter of heat, collected and condensed by electrical operations.*

All this, however, has been already noticed in the preceding parts of this course. At present we must confine ourselves to the examination of the variety of waters found in nature, and to an account of the means which chemistry furnishes for investigating their qualities and contents.

The natural varieties of waters are produced by the union of various other substances, in different proportions, commonly very minute, with this fluid. And it is never found perfectly pure from these, though in some cases it is very nearly so.

When we have occasion for water quite pure, to be employed in nice chemical operations, we must procure it by

* I observe some authors complimenting the sagacity of Sir Isaac Newton, by saying that he conjectured, from its great refracting powers, that it contained an inflammable substance. I have never met with this assertion by Sir Isaac Newton: and it is surely a mistake; for the fact is, that water has the smallest refracting power of any liquid that we are acquainted with. Sir Isaac indeed says, that the great refracting power of the *diamond*, makes him imagine that it contains inflammable matter.....EDITOR.

art. We must choose good spring water, or rain or snow-water, collected at a distance from the smoke of many houses, and distil it until we have got two-thirds, or three-fourths, and reject the remainder.

The varieties of water found in nature may be all comprehended under the six denominations of

1. Rain water.
2. Fountain water, and well water.
3. River water.
4. Water of lakes.
5. Water of marshes and shallow pools.
6. Sea water.

Of these natural waters, rain water, when properly collected, comes nearest in purity to distilled water. It is water distilled by nature ; and would be quite pure, but for the vapours of the atmosphere. To have it in the greatest degree of purity of which it is capable, it must be collected at a distance from the smoke of houses, or other causes which occasion vapours or effluvia to mix with the air. The rain water which runs from roofs, however, is very impure and sooty. Sometimes too it has happened, that showers of rain have fallen mixed with the staminal dust of plants, which has been mistaken for sulphur.

The waters of springs and wells consist of rain water, which has soaked through crevices and the more porous parts of the earth, until it has been stopped in its progress downwards, by impenetrable strata of clay or other matter, and breaks out again in some lower part of the earth's surface.

The opinion which was once formed by some philosophers concerning the origin of springs, is very absurd,... that they are fed by the sea; that the sea water filtrates through the pores of the earth, and ascends through the interior parts of the high lands and mountains: that the salt is separated from it during this filtration; and that the water breaks out at last to form the springs. It is absurd to suppose that the water can ascend in this manner, contrary to its gravity, or that the salt can be separated by filtration. It is plain that rain water falls most plentifully upon the mountains and high lands: and as a great part of it

is absorbed, and penetrates into the porous parts, of them, it is abundantly sufficient to account for the origin of springs. And we have a proof from the experience of miners. The deeper they go, the less water they meet with.

Spring water must therefore necessarily be less pure than rain water; as the water may find various substances in its way through the earth, which it will dissolve and partake of. Some springs, however, give a water remarkably pure. Such are those which are filtrated through sandy and gravelly soils, or through mountainous countries, composed of harder and more undissolvable stones. Others contain a variety of matters; and these sometimes in considerable quantity, and of such a nature as to give them medicinal efficacy. For this reason, after we shall have shortly considered the other more general varieties of natural waters, we shall return to the varieties of spring waters, and explain them more particularly, with a view to point out the proper method of examining mineral springs, and for discovering the principles they contain.

The water of rivers is composed entirely of the waters of springs, and of such rain water as runs along the surface of the ground, without sinking into it. It is therefore various in different places. Thus the water of rivers which pass through very large cities, as the Thames does, becomes so loaded with animal and vegetable matter, as to be susceptible of a high degree of corruption. In general, however, the water of those large rivers which are not exposed to such causes of impurity, though often troubled with atoms of mud and clay, when refined from these by rest or filtration, are rather more pure and wholesome than the water of the greater number of springs or wells. The reason seems to be, that they are composed partly of rain water, which has not penetrated the soil, partly of the water of springs, which, while it runs a considerable way along the surface to join great rivers, becomes generally purer. Some of the principles it contains are volatile: a greater number are dissolved in the water by means of those volatile ones, and are deposited when they evaporate. Whether the purity of river water depends on these circumstances or not, it is certainly very remarkable in some cases.

The water of large lakes, having the same origin with river water, is equally pure, except in a few examples of lakes situated in countries which abound with salt; and is in general much more transparent, in consequence of its stagnation, which allows all the muddy particles to separate to the bottom. But small pools and marshes, and other shallow collections of stagnating water, are in general very impure and unwholesome. The heat of the sun has a strong effect upon these, and occasions quick and multiplied successions of animal and vegetable productions in them. The vulgar have been astonished and terrified at the sight of a red colour which such waters sometimes assume, as if suddenly changed into blood. This arises from insects. The putrid damps which arise from such waters in hot climates, or rather from the marshes which they leave when they dry up, are causes of numerous diseases, agues, dysenteries, &c.

The last variety of water which we enumerated, sea water, is still farther removed from the state of purity than any of the former. Near the shores especially, it is not only rendered impure by the muddy particles brought into it by the rivers, and those stirred up and kept afloat by the waves; but as it contains innumerable animals, these must contribute, by their different excretions, to its impurity. The admixture, however, by which it is the most remarkably distinguished from pure water, is that of different saline substances, which it contains in very considerable quantity, in consequence of which it has a strong taste, and is totally unfit for the use of man, and other land animals.

The nature of these salts, and saline compounds, which sea water contains, has been investigated by different chemists.

First, Dr. Gaubius of Leyden, who made his experiments upon 50 pound of the sea water, and has published them in his *Adversaria*.... From 50 pound of 16 ounces Troy weight of sea water, Gaubius obtained,

	oz.	dr.	gr.
Common salt, some of it impure	20	4	1
Selenite, and what he calls <i>alumen muriaticum</i>	1	1	0
Sal dictum Glauberi	2	4	0

Bergmann examined sea water, taken up for him by Mr. Sparmann from a depth of 60 fathoms, in the latitude of the Canary Islands. He obtained from it,

	oz.	dr.	gr.
Common salt - - - - -	37	5	26½
Magnesia muriata - - - - -	10	2	14
Gypsum - - - - -	1	1	4½

He examined it very scrupulously for magnesia vitriolata, but found none.

Dr. Higgins obtained from sea water of our climate,

	oz.	dr.	gr.
Common salt - - - - -	23	3	36
Magnesia muriata - - - - -	10	1	12
Gypsum - - - - -	1	1	44

To imitate sea water, suppose 50 pound of it to contain 25 ounces of common salt, and 10 ounces of muriat of magnesia. Each gallon English will contain four ounces of common salt, and 13 drachms of muriat of magnesia; which 13 drachms of muriated magnesia will probably be contained in 26 drachms of what is called oil of salt.

Dr. Higgins remarks that the magnesia salita appears to be the most efficacious ingredient in sea water. The proportion of it to the sea salt is as eight to 18½. And as persons are cured of diseases by sea water, who eat sea salt every day of their lives with their food, there is no reason to impute their recovery to the sea salt.

It is usual, therefore, in the practice of medicine, to imitate sea water with a mixture of common salt and purgative salts dissolved together: and the solution may be made so strong that two spoonfuls, or a little more, may prove a dose. But to resemble sea water, it should always be greatly diluted when taken.

Sea water proves a useful medicine in some cases, though taken in smaller quantities than what prove purgative. It is thought, when taken in this manner, to have some efficacy in removing obstructions and tumours of the lymphatic glands.

And some have imputed these effects to its septic power, whereby it dissolves concretions of the fluids. It contains less than Sir John Pringle's septic quantity of common salt. But its medical efficacy does not appear to me in this light. Putridity weakens the power of the vital or animal principle, and increases all diseases. I should rather impute it to a general stimulus, by which it promotes all the secretory motions in the body. It is certainly in some measure by a stimulus exerted upon the skin, and by which it promotes perspiration, that bathing in sea water has been so beneficial in these and other diseases.

Such is, therefore, the general outline of the variety of natural waters. To return now to the waters of springs.....

In order to give you a general view of the variety which occurs among spring waters, I must, in the first place, enumerate the different substances which have been found in them by chemical experiments, and mention some remarkable qualities which some of them are known to possess.

Thus, 1st, Some are warmer than the medium heat of the latitude in which they are found.

The water of common springs always has at its source the medium temperature of the climate in which it is found. In Edinburgh, this medium temperature is 48° ; in London 52° ; about Paris 55° ; farther south, higher. But springs are found in many places, the heat of which is considerably above these medium temperatures: and there is great variety in respect of this superior heat. Some are boiling hot; others scalding hot; others only tepid; and so on. The most surprising particular in the history of these springs is the amazing quantities of hot water which some of them throw out, without the least apparent variation of this quantity, or of the heat; a certain proof that they receive their supply of water and heat from a great depth. Such are the springs at Bath.

The cause of this heat is a subject of many opinions. There are, doubtless, chemical changes going on in many watery solutions in the bowels of the earth, in which heat is extricated. But I cannot conceive any such, where the result is pure water, such as flows from the Bristol hot well. In such cases, the cause of the heat is certainly subterranean

fire. No other cause is adequate to the effect: and we know that these fires exist, and have existed at all times. In agreement with this opinion, hot springs are most frequent in volcanic countries. There are many in Italy and in Iceland. Geyser, in the neighbourhood of Hecla, in Iceland, emits an immense body of water by several openings. Two of them are very remarkable. The one, called the old Geyser, throws out water by a perpendicular pipe, nine feet in diameter: and it sometimes throws the water up in the air 200 feet. Sir Joseph Banks, &c. saw it rise about 90; also Mr. Stanley. *Vide vol. ii. of Edin. Trans.*) Some hot springs are at a great distance from volcanoes. But how is subterranean fire supplied with air? I may answer, that water carries air with it to these fires, and is converted into air by chemical operations; some of which are known to us, while others are equally certain, although our chemical knowledge cannot yet explain them.

To proceed. Beside this heat, found in some springs, we find also in many, as was formerly observed,

2do, Carbonic acid, the quantity of which is very various. Some are so much saturated with it, that it comes out of them as from some fermented liquors. It is generally attended by other admixtures.

3tio, The fossil alkali is not uncommon, sometimes combined in part with carbonic acid, but much more frequently with the muriatic. Some authors also mention the volatile alkali as having occurred. I believe, however, that if this ever happen, it is exceedingly rare.

4to, The sulphuric, or the muriatic acid, or both together, are very often present in these waters: but they are always combined with the fossil alkali, or with some alkaline earth, or with a metallic substance.

5to, The only alkaline earths hitherto discovered in spring waters are the calcareous and magnesia. They are either in the form of carbonats, that is, dissolved in the water by means of the carbonic acid, or they are combined with the sulphuric or muriatic acids.

6to, The argillaceous earth is rarely found dissolved in these waters, but when it occurs, it is always combined with the sulphuric acid.

7mo, Geyser is the only example known to me in which the flinty earth is found in spring water. It is dissolved by means of fixed alkali.

8vo, Of the inflammable substances, we sometimes find sulphur, or sulphurous gases, and more rarely, some of the fossil oils. These last appear mostly in drops upon the surface of the water. The sulphur, when it occurs, is more intimately combined or dissolved, and this by means of fixed alkali, or of hydrogen, so as to form inflammable gas.

9no, Some of the metallic substances are the last which we need to enumerate among the contents of spring waters. And no more than two have, in my opinion, been certainly demonstrated in their composition,....iron and copper.

Iron occurs very often; and is commonly dissolved in the water by the sulphuric acid, and sometimes, as is supposed, by fixed air. Copper but rarely appears; and is always dissolved by the sulphuric acid.

Some authors mention also zinc and arsenic as occurring sometimes: but I have not met with proofs of this. The ores of zinc are not liable to that vitriolization by the action of air, to which those of iron and copper are often disposed, and which converts them into compounds of metals and sulphuric acid. And as for arsenic, though of itself soluble in water, it does not dissolve without boiling heat. Were it ever to make its appearance in waters, the presence of it in their composition would be but too manifest by their pernicious effects.

These are the different substances which have been plainly demonstrated in different spring waters. And they are found in the different springs in great varieties of number and proportion, only that in general the proportion of them to the water is very small. Those that predominate in any particular spring, give to the water particular qualities and a particular character, in consequence of which, the springs reckoned medicinal have been distinguished by physicians into a number of different kinds, and by different denominations, which I shall next explain.

1st, Those that are warmer than the middle temperature of the place where they are found, called hot or tepid springs.....

Therma.

2d, Those in which carbonic acid predominates, so as to give them a sourish taste, and briskness.....*Acidulæ*.

3d, Those that contain an alkaline salt not completely neutralized with acid.....*Fossil alkaline waters*.

4th, Those which contain such a quantity or variety of saline matters, as render them purgative.....*Purging springs*.

5th, *Chalybeate waters*.

6th, *Sulphurous waters*.

These are the general distinctions of medicinal springs among physicians, who thus discriminate them by some of their sensible qualities or medicinal powers.

But some other qualities have been observed in spring or well waters, which have occasioned other distinctions and denominations of them among common observers. Thus,

7th, Some are called *hard*, or springs or wells of *hard water*. These do not dissolve soap well, but produce a greasiness on the surface: and they are ill qualified for boiling vegetables, and for penetrating and dissolving their soluble parts. The infusions of tea, or other vegetables, in these are weak and bad. They contain a compound of some fossil acid with other matter, by which it is not so completely neutralized as to prevent its acting on the alkali of soap.

8th, Some are called *petrifying waters*. They contain calcareous earth dissolved by carbonic acid.

9th, Some are called *salt springs*. They yield common salt with profit.

10th, *Coppery springs* contain copper separable by iron.

11th, *Bituminous springs*, are so called,....drops of bitumen being commonly found floating on their surface.

And now I have said enough to enable you to form some general notions of the variety of spring waters which occur in nature. We shall next attend to the manner of examining them, in order to learn which of these substances now enumerated, or how many of them, they contain.

In examining mineral springs, 1mo, Observe the situation of the spring, and nature of the soil and country around it, and whether any minerals are near it, or within the distance of a few miles. They often receive some of their contents from a mineral vein.

2do, Observe its heat with a good thermometer, and also the colour, taste, smell, and other sensible and obvious qualities of the water. Deep glasses are the best for shewing colour or clearness.

3tio, In order to the examination of the more fixed ingredients, evaporate one or more gallons of it with a gentle heat to dryness. This evaporation may be performed, at last, in a small China bowl, that the extract of the water may be the better collected together, and the more easily taken out; and the bowl should be heated only with the steam of water. The quantity of the dry extract can be exactly ascertained by weighing the bowl before and after the evaporation: and the different ingredients of it are to be investigated by an analysis.

We must next investigate the materials which compose this dry extract, by the application of different solvents and other agents, such as *1st*, Alcohol: *2d*, Distilled water applied cold: *3d*, Distilled water applied hot: *4th*, Acids. Alcohol dissolves the compounds of magnesia or calcareous earth with muriatic acid, but leaves untouched all other compounds. A moderate quantity of cold water dissolves all the other saline compounds, except gypsum: and gypsum is dissolved and separated from the mere earthy matter, by 500 times its weight of boiling water, or that quantity of distilled water boiled with it some time.

These different solutions may afterwards be evaporated for crystallization; or we may easily learn, by other trials to be mentioned presently, what acid and what quantity of it they contain, and with what matter this acid is joined.

4to, A set of experiments are to be made on the water itself in its entire state. And they are made by adding different chemical agents, which produce remarkable effects on the various substances which the water contains, or are affected themselves remarkably by them, to such a degree that we are enabled in this manner to detect the most minute quantity of these substances. Of these experiments I shall mention some examples, while I describe the manner of investigating the contents of mineral waters.

I....Experiments to discover the Carbonic Acid.

1. Attend to the obvious qualities which it produces, viz. briskness like that of a fermented liquor, and a pungent sourish taste, both of which are lost by exposure to the air, especially with agitation.

2. It strikes a red colour with litmus, which disappears by exposure to the air for some time.

3. Lime-water, being mixed with such aërated water, precipitates the lime, which will be redissolved if there be much of the air, and if we have not employed enough of the lime-water.

4. To measure the quantity, a bladder is tied to a bottle, and the air is expelled by heat.

This is the method which has been often practised, and which may be practised when we cannot do better : but it is not exact. A part of the air is very liable to escape at those places where the bladder is tied : and some of it penetrates through the bladder, or is absorbed by the water with which it is soaked. A more exact way is to fit a cork very close to the mouth of the bottle, and then, making a hole through the cork, fix in it a bended glass tube. The bottle being then quite filled with the water, put in the cork, and make the extremity of the bended glass tube dip into a cistern of quicksilver, in which stands inverted a cylindrical vessel, also filled with quicksilver. The air expelled from the water by heat, will rise through the tube into this cylinder, and displace the quicksilver : and thus it is both collected and measured at the same time. And in order to learn the quality of it, we may apply caustic alkali, or lime and water to it, to know how much of it is carbonic acid gas, which will be quickly absorbed ; and we may afterwards examine the remainder.*

II....Experiments to discover Alkaline Salts.

To learn, in the next place, whether or not there is any alkali not completely neutralized with fossil acids, or combined only

* We may also learn its quantity with considerable accuracy, by the weight of the precipitate which it occasions from lime-water,....having taken care that an excess of lime-water has been employed. The air may be estimated at eleven-twentieths of the dried precipitate.. EDITOR.

with the carbonic, we may use some of the vegetable tinctures, or infusions of flowers, that are the most easily affected by alkalis. The syrup of violets is that which is commonly used: but I find an infusion of the flowers of mallow more convenient. The colour is produced exactly the same, whether the alkali be fixed or volatile: but we can easily distinguish which of the two it is, by a subsequent experiment with the muriat of quicksilver. And if we find it to be a fixed alkali, we are sure it must be the fossil alkali. The quicksilver, when oxydated, has a remarkably strong attraction for volatile alkali,....a small portion of which unites with it in this case; and forms with it, and with a small part of the muriatic acid, a mercurius dulcis, insoluble in water.

These experiments, therefore, give indications of alkaline salts not completely neutralized with fossil acids. But if alkalis be present, combined with one or more of these into neutral salts, they are best discovered and distinguished by examining the extract of the water obtained by evaporation, and the different saline compounds into which it can be analysed.

III.....Experiments to discover Sulphuric Acid.

This is often present, combined with some other matter. With whatever substance it be combined, it can always be detected by the muriat of nitrate of barytes, the barytes having the strongest attraction for the sulphuric acid, with which it forms a compound insoluble in water. To make this experiment quite satisfactory, however, we must add a small quantity of nitric or muriatic acid, perfectly pure, or free from sulphuric acid; for the barytes may be precipitated by a carbonat of alkali. But if this happen, a small addition of pure aqua-fortis will redissolve it.

IV.....Experiments to discover the Muriatic Acid.

This acid can as certainly be discovered by the solution of silver with excess of acid.

We do not learn, however, by these trials, what matter these acids are combined with: but this appears, either from some of the other trials we have to mention, or from the examination of the fixed matter obtained by evaporation.

I observed before, that these acids are hardly ever found in the waters in a non-saturated or pure state; though this is said by some authors, who have probably been imposed upon by the taste and qualities of the acidulæ or æreal waters. But turnsol would detect them.

V.....Detection of Earths in Mineral Waters.

Earth, when present, is seldom any other than calcareous earth, or magnesia, or both, combined with some solvent, either carbonic acid, or some of the fossil acids. I have always observed, that in the waters containing those carbonats, there is also a quantity of the earth combined with some other of the fossil acids. The part dissolved by carbonic acid, is discovered by boiling the water in a clean vessel. The acid is expelled, and the earth precipitates.

Bergmann says that the calcareous earth, suspended by æreal acid, soon separates from the water by moderate boiling; but that magnesia, in the same state, separates gradually, during the whole time that the water is boiled or evaporated to dryness. Water fully impregnated with carbonic acid will dissolve more than one-fortieth of its weight of magnesia, every ounce holding above twelve grains. The tufa formed by the evaporation of such waters, has been generally considered as calcareous: but it always contains magnesia, and sometimes a great deal. Strata of limestone are met with, containing so much that they are unfit for manure, and even pernicious. This is the case in the neighbourhood of Doncaster.

The nature of the earth which separates in this manner is determined by combining it with the sulphuric acid.

There is another method, better fitted for detecting the smallest quantity of earth suspended by means of carbonic acid. This is done by dropping into the water some solution of the acetite of lead. The lead is precipitated, and the earth suspended by the acetous acid. But as the lead would also be precipitated by a sulphat, we must add some more acetous acid. This will redissolve the lead, if it has been separated by means of an earth. But observe that saccharum saturni does not shew a small quantity of earth, if there be much carbonic acid in the water.

When the earth present in water is dissolved by some of the fossil acids, it may be separated by carbonat of fixed alkali, which however is best added after the water has been evaporated to one-fortieth, or one-fiftieth, or rather after it has been evaporated to dryness; the soluble parts of the residuum being redissolved with distilled water, and the alkali added to this solution.

The nature of the earth is determined, 1st, By distilled vinegar applied cold, which will dissolve calcareous earth, or magnesia, but not argillaceous earth.

2dly, By sulphuric acid, which precipitates the calcareous earth from the vinegar in form of gypsum, but with magnesia forms a soluble compound.

Professor Bergmann also recommends the oxalic acid, or the acid of sugar, as a means for detecting the smallest quantity of the calcareous earth in particular, and in whatever manner it be dissolved. It is sure to unite with this acid, for which it has a much stronger attraction than for any other, and always forms an insoluble compound. And this is perfectly true. The precipitation, however, is not so quick, or so remarkable, as in some of the experiments already mentioned, especially with the acetate of lead.

If there be any siliceous earth dissolved in the water, we shall be sure to find it in the matter which the water affords when evaporated to dryness. After we have extracted the saline compounds and salts from that matter by alcohol, and by distilled water, applied first cold, in moderate quantity, and afterwards hot, in large quantity, mere earth will remain, which must be treated first with distilled vinegar, which will dissolve calcareous earth or magnesia; afterwards with some of the fossil acids, which will dissolve the argillaceous earth, if there be any. But if a quantity of tender, light and spongy earth remain, on which the acids produce no more effect, there is reason to think that it is siliceous: and we can assure ourselves that it is such, by mixing it with an equal weight, or one-half of its weight, of dry carbonat of soda, and heating this mixture strongly with the blow-pipe in a platina spoon. If the earth is siliceous, it will melt into glass.

VI....Detection of Sulphur.

Having now shewn the means for discovering the presence of salts and of earths, in the composition of mineral waters, the means for detecting the presence of sulphur are next to be described.

Sulphur has been found in two states in sulphurous waters: 1st, Either combined with an alkali, and forming an alkaline sulphuret, (this I believe is exceedingly rare): or, 2dly, In the state of a sulphuret of hydrogen, or sulphurous hydrogen gas, which, you know, is soluble in water.

The nature of this compound was first investigated by Professor Bergmann. He also shewed that it can be prepared by art, and so combined with water as to form a sulphurous water of this volatile kind.

The indications of a sulphurous mineral water are,

1st, Odour of *hepar sulphuris*, perceived on approaching the spring. This is a sure and nice indication.

2dly, A common trial is to put a piece of silver into the water, which is quickly tarnished and blackened. I find that other metals are fitter, *e. g.* lead is quickly blackened.

3dly, A mark made with acetite of lead, or tartrite of bismuth, on paper, is exceedingly effectual and sure. A true hydro-sulphuret, dissolved in water, (that is, a volatile sulphurous water) blackens these substances very speedily, even when brought very near them; and they do this without suffering any decomposition, indicated by milkiness or turbidness. But a sulphuret of potash or soda dissolved in water, though it blackens these substances as quickly, is always decomposed by it. To learn the quantity of the sulphur,

1mo, If any part of the sulphur is dissolved in the water, and kept suspended by an alkaline substance, a little of the sulphuric or muriatic acid will precipitate the sulphur, which, being afterwards collected on a filtre, can be weighed by itself. But these acids never precipitate the whole of the sulphur from such waters; a part of it being combined with inflammable air, and dissolved in consequence. And many waters have all the sulphur which they contain dissolved in this form. In this case

the sulphur cannot be precipitated by diluted sulphuric or muriatic acid.

2do, But we have other acids that can precipitate the sulphur in this case, and these are the strong red nitrous acid, and the sulphurous acid. The first was recommended by Bergmann, and the second by the French chemists. This precipitation is supposed to be produced by the action of the oxygen of the acid on the hydrogen of the gas. These two principles unite together to form water, and the sulphur, when thus left alone, is not soluble in water. But there is a difficulty attending this account of the matter: for, if it be well founded, we cannot find a reason for this inefficacy of the nitric and sulphuric acids to precipitate the sulphur *equally well, or better*, as they contain more oxygen than the nitrous or the sulphurous acid. Moreover, when the oxygen is taken from the sulphurous acid, why is not the sulphur which that acid contains precipitated also, along with that of the water? As this does not happen, Mr. Berthollet and Fourcroy suppose that only a very small portion of oxygen is taken from the sulphurous acid, or supplied by it: and accordingly, when the water is examined after the precipitation of the sulphur, the sulphurous acid is found still existing in it.

3tio, Several metallic oxyds also can be employed to attract the sulphur from these waters,....cerussa, or white lead, for example. Litharge also has the same power, and the oxyds of quicksilver, and some others, particularly white arsenic. These oxyds act partly by their oxygen, which unites with the hydrogen of the gas, and partly by their own attraction for sulphur.

4to, Some solutions of metals in acids are still more convenient indicators, as they enable us to ascertain the quantity of the sulphur. One of the best for this purpose is the solution of muriat of quicksilver. An æthiops, or sulphuret of quicksilver, is produced, from which we can easily separate the quicksilver by acids, to have the sulphur pure; or we can first weigh accurately the precipitate, then revive the mercury, and, by the quantity of it, know how much sulphur was joined with it. You know that the muriat of quicksilver contains this metal highly oxydated. The oxygen unites with the hydrogen of the gas, and the quicksilver thus metallized unites with the sulphur.

VII.... The only other inflammable substance which has been found in waters, viz. bitumen, is obvious to the senses.

VIII.... Metals are the last of the substances we enumerated, as found in waters,...and iron is the most common. It is often combined with sulphuric acid, sometimes, however, with carbonic acid.

The possibility of dissolving iron in water by carbonic acid, or fixed air, was first discovered by Mr. Lane, and communicated in the Philosophical Transactions of the Royal Society.

In authors you will find the Prussian alkali recommended for detecting metals in general, and even for distinguishing them. It precipitates iron blue, copper of a red or coppery colour, and zinc white. There is, however, some uncertainty in the indication of this test. It is a very difficult chemical problem to prepare this alkali altogether free from iron. We have a better test of this kind by combining the tinging matter, not with alkali, but with lime. Lime-water, boiled a little on Prussian blue, will completely deprive about one-thirtieth of its weight of all the colouring matter, without taking up any martial oxyd; and is a very sure and expeditious test of the presence of iron. For this purpose, it must be carefully kept in well stopped phials, and even screened from the light.

The appearance of ochre in the channel of the little stream formed by the water flowing from the spring, is also a very nice indication of iron.

Astringent vegetable matter, and especially the gall-nuts of the oak, will discover an astonishingly small quantity of iron in these waters. It sometimes happens, however, that the dark colour does not appear when the powdered galls are added to a water which contains iron. This proceeds from an excess of acid, and is easily obviated, by adding a very small quantity of alkali. We can make the colour appear and disappear repeatedly, in a mixture of this kind.

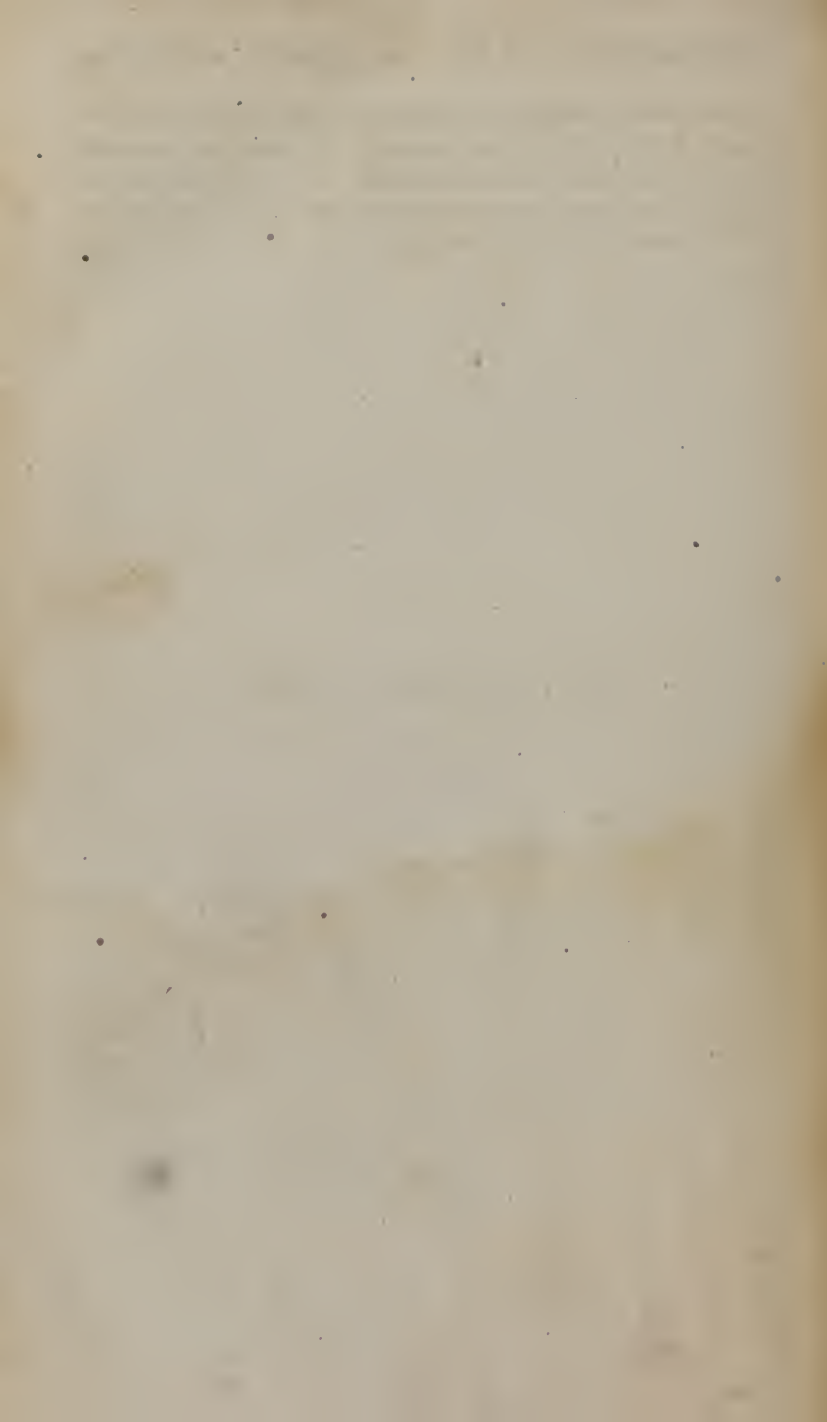
As for copper or zinc, their appearance is very rare: and we need not have recourse to this trial to discover them. There are others that are better.

For the art of imitating the different mineral waters which are esteemed in Europe, and made objects of commerce, you may consult Professor Bergmann, whose work on this subject, and

on the manner of analysing mineral waters, is one of the most valuable he has left us. More lately, Mr. Fourcroy has published a laboured and accurate analysis of a sulphurous water in France, at Enghien, in which he has given many judicious and useful remarks on the use of precipitants in examining these waters.

END OF THE THIRD VOLUME.

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NOTES AND OBSERVATIONS.

BY THE EDITOR.

[*Note 46. p.30.*]

IT will be of some service to us in our future consideration of this subject, to recollect the well known fact, that any plant, the sugar cane for example, will grow from a minute seed to maturity, yielding sugar and every other production competent to its nature, if planted in pure sand, fed with distilled water, and having a free communication with the air and light, and a proper degree of warmth. The sand in which it grew is neither diminished nor changed in the smallest degree. It would seem, therefore, that we must expect nothing from alcohol but what is supplied from these sources, viz. the water, the atmosphere, light, and heat; and that it is to these that we are to look for the oxygens, hydrogen, azote, carbon, alkali, and every thing that we obtain from alcohol.

[*Note 47. p. 35.*]

Dr. Black has attended to those circumstances only of the process which relate to the preparation of æther. It is therefore proper to mention, that, at the time when the white cloud prescribes damping the fire and changing the receiver, another singular product begins to form. This drops from the spout of the retort into the water in the receiver;

and is the *sweet oil of wine*, an oily, fragrant, and sweet tasted fluid. With whatever care the process is now conducted, the matter in the retort being now much hotter, the vapours of sulphurous acid now rise, and must be allowed to escape: more oil comes over, but horribly tainted with these vapours, and growing more and more thick and dark coloured,... at last quite dirty. This is owing to a perfect charcoal, now formed in the retort, so light as to rise with the vapours. At last, the matter in the retort becomes a dry, pitchy-like, spongy mass.

[*Note 48. p. 35.*]

It would never appear in the fluid form in these climates, but in that of elastic vapour, did not the pressure of the air keep its particles from flying asunder. This must bring to our recollection Dr. Cullen's experiments, which were of so much use to Dr. Black, for establishing the doctrine of latent heat.

If a wide glass cylinder, fitted with a piston, which is put half way down, be filled with the pure vapour of æther, kept of such a temperature that it just balances the pressure of the air, and if the piston be then suddenly drawn to the top, the cylinder will be filled with a white cloud, which lasts for a second or two, and then disappears. This shews that it is not merely *capacity* for heat which fits the vapour for appearing in its more expanded form. This form is the consequence, and not the cause, of the absorption of heat.

[*Note 49. p. 100.*]

I cannot but think that peat, or the black moss of the moors, is an approximation to coal. Peat is not found in many places; and no where abounds so much as in Scotland and Ireland. It is by no means enough for the formation of peat, that the place be a wet marsh, abounding in vegetable matter. In immense districts of Europe and America, such situations are common; and we have impassable morasses and swamps of vast extent. But these are not filled

with peat; nor is the mud which fills them very inflammable. Accustomed to the bogs of Scotland, and little informed in natural history, I was much surprised at finding similar situations in the Canadian woods without peat; and this made me examine with attention the matter contained in those bogs. Even where the vegetable remains were very abundant, and constituted almost the whole mass, I found it very little inflammable, and altogether unfit for a fuel. And what I took particular notice of, the smell in burning was altogether unlike the smell of burning peat. This is quite peculiar to peat. I never saw peat in any part of North America, except in the neighbourhood of Louisburg: and there it was but a very scanty mixture of peat-earth with the moorish soil.

While the smell of all burning peat has a character by which it may always be known, there are considerable varieties; and these varieties seem to me to be super-additions to the distinctive smell of peat. This is considerably like that of the most inflammable lean coal, and still more like to that of jet, but not near so offensive. The blackest, hardest, heaviest peat, when the matter is almost an impalpable pulp, is the most inflammable, and leaves the smallest quantity of ashes. This kind of peat has the heaviest sickening smell. Such is the peat at Canisbay, in the north extremity of Scotland, just by John-a-Groat's House. This, when dried, is so fine in its texture, as to break with a sort of polish, like a jasper. Its smell in burning is not very distinguishable from that of cannel coal. The smell of the best Dutch turf, which is taken up from the bottom of salt water, very much resembles that of the peat now mentioned.

I am inclined to think that a certain juice is necessary for the formation of a bog into peat. Perhaps this juice is the primitive bitumen. I suspect also that it is always accompanied by vitriolic matter. Peat ashes always contain a very great proportion of iron. I have seen three places in Russia, where there is superficial peat moss: and in all of them the vitriol is so abundant as to effloresce. One in particular, adjacent to St. Petersburg, shews it every morning on the clods, when the dew has dried off.

Peat mosses form very regular strata, lying indeed on the surface; but if any operation of nature should cover this with a deep load of other matter, it would be compressed, and rendered very solid; and remaining for ages in that situation, might *ripen* into a substance very like pit-coal.

[*Note 50. p. 118.*]

Perhaps the fact would be more properly expressed by saying that when the effervescence produces hydrogenous gas, the French chemists, combining their theory of combustion with Mr. Cavendish's discovery of the composition of water, infer that the metal acted only on the water, and, attracting its oxygen, sets the hydrogen at liberty. When azotic gas, or nitrous air, is yielded by the effervescence of a solution of metal in nitric acid, they say that the metal acts on the acid, attracting its oxygen, and thus liberating the azote. Before Mr. Cavendish's discovery, the solution of metals in the sulphuric and muriatic acids presented difficulties which greatly embarrassed the partizans of the new doctrine. This accounts for their anxious and laborious repetition of the experiments of Mr. Cavendish. Till this doctrine was firmly and accurately established, the theory of acidification was quite unsatisfactory. Nor did even the composition of water make it of extensive influence, till the proportion of the gases was exactly ascertained.

It must be acknowledged that the order in which metals appear to attract the acids in solution corresponds pretty well with the order in which they are oxydated by the action of heat and air. Zinc and iron precipitate all other metals from the nitrous acid: and these metals are more calcinable than most others. Tin, however, does not fall into its place in the order of solution: it is very calcinable. It is also pretty conformable to the same principle, that zinc, iron, and tin, produce inflammable air, that is, decompose water by their strong action on the oxygen. But were this the sole efficient cause of this peculiarity of those metals, we should expect it in a much more remarkable degree in cobalt, magnesium, and tungsten, which calcine so rapidly by mere exposure to the atmosphere. Nay, the white oxyd of magnesium should do it. But none of these

substances produce, as far as I can learn, inflammable air from diluted sulphuric acid. &c.

I would say farther that the application of this theory to the complicated cases of animal and vegetable substances is, in a great measure, gratuitous, till we shall have ascertained, not only the proportion of the ingredients, but also their elective attractions in all different temperatures. This seems peculiarly necessary with respect to the basis of the three gases, which act such important parts in these changes. Till this knowledge be attained with considerable precision, it will always be easy, by ringing the changes (so to speak) on oxygen, hydrogen, and azote, and by taking their several actions in any order of succession that we please, it will, I say, be easy to explain any phenomenon whatever. I must add, that some of those elective attractions appear to me to be such as to render some of the favourite explanations of these phenomena inadmissible. I think that I shall be able to give instances, before we arrive at the end of these lectures.

[*Note 51. p. 124.*]

These Dutch gentlemen do not choose to consider these facts as examples of combustion ; because they say that there is no decomposition or change effected in either of the ingredients. It is a mixture, like that of sulphuric acid and water, in which also there is a vast extrication of calorique ; because the capacity of the mixed is less than the sum of the capacities of the ingredients while separate. Or it is the extrication of latent heat. They explain these facts in the same manner. There is, indeed, another case, in the mixture of metal with sulphur, in which this explanation is very admissible, namely, the incandescence (and actual inflammation, if in the air) of mercury and sulphur, in the preparation of cinnabar. But in the facts mentioned above there are very essential differences of circumstances.

I have not seen the account which the Dutch chemists have published of these experiments ; and have read only Van Mons's repetition of them, of which a very distinct abstract may be

seen in the *Analytical Review*, for October 1795. I do not know, therefore, the precise state of the compounds. This is certainly a chief circumstance, with respect to the theory of the phenomenon. It was surely a very unexpected circumstance, that zinc should exhibit such an appearance of inflammation, seeing that this metal contracts no union with sulphur.

We must at any rate conclude from these experiments, that oxygen gas is not the sole source of the light and heat which appear in the combustion of bodies, which seems to be a point of doctrine in the antiphlogistic system of chemistry. The great heats produced during the solution of metals in acids, notwithstanding the eruption of much gas containing oxygen, present, I think, a difficulty in this system. It is somewhat lessened by these Dutch experiments. For we see so much heat extricated as to produce ignition; and therefore may more easily conceive the change of capacity in solution to be adequate to the production of the smaller heats which appear in that process.

The heat and light also, in all deflagrations with nitre, are another indication of a great quantity of caloric combined with oxygen and with azote in the nitre, in their solid form.

From such facts, it may perhaps be concluded, that the emission of heat and light is more copious in ordinary combustion than in the other cases before us, only by the emission of what was *further* combined as indispensable articles of the gaseous form in which oxygen and azote exist in the atmosphere, that is, by the emission of the latent heat of Dr. Black; a state of the caloric different from that which requires a proper third substance, along with a high temperature, to disengage it by superior affinity.

But, although these considerations give a greater consistency to the new doctrines, and lessen some of their difficulties, the intelligent reader must, I think, perceive that the whole becomes hypothetical, and all the properties, affinities, and other relations of these supposed bases of different kinds of gas, are mere interpretations of the phenomena; or rather are accommodations and corrections of supposed properties, till the hypothesis is made to tally at last with all the phenomena. The hypothesis seems to have nearly the same rank in science with the

magnetical hypothesis of *Æpinus*. Both are ingenious and elegant, in the highest degree; and have such a comprehensive resemblance to the phenomena, that the hypothetical principle becomes an excellent principle of arrangement or classification of the phenomena, almost equivalent to a just theory, and, in all probability, extremely near to it. Other cases occur in the subsequent lecture which will bring this subject again before us.

[*Note 52. p. 183.*]

Dr. Black having only given the general conclusions which have been drawn by these eminent chemists concerning this very singular substance, it seems necessary to mention the chief and most simple facts by which these opinions are supported.

If we boil the prepared alkali, called the *lixivium sanguinis*, or *Prussian alkali*, with a diluted sulphuric acid, vapours come off which are extremely volatile. When the distillation is skillfully conducted, the first vapours are found much more volatile than water; and cannot be condensed, unless water be mixed with them, or presented to them in the receiver. This vapour has a strong smell, not disagreeable, and is extremely inflammable.

This substance contains the colouring principle; and the *lixivium* now possesses none. Its taste is sweetish and astringent. But as this watery solution of it unites with all alkaline substances, and with metallic oxyds, and may be detached from one of them by means of another, in the same manner as acids, it is considered, chemically, as an acid, and has been called the *PRUSSIAN, or PRUSSIC ACID*: and its compounds have been called *PRUSSIATES*. That compound, called the *lixivium sanguinis*, prepared, or *Prussian alkali*, &c. is the *PRUSSIATE OF POTASH*.

The prussic acid, prepared in the way just now mentioned, is but impure. Dr. Scheele procured it in the greatest purity, by first forming of this impure acid a prussiate of mercury, and then putting some filings of iron into it and a small quantity of sulphuric acid. This instantly decomposed the mercurial prussiate, and even greatly weakened the attraction of the Prussic

acid for the iron, by the excess of sulphuric acid. The mixture being now distilled with an extremely gentle heat, and the first vapours only preserved, the result was a prussic acid perfectly pure. With this, or such as this, all the experiments for ascertaining its properties are tried.

It combines, as I have said, with all the substances which combine with acids, with various degrees of elective attraction. Lime water digested on Prussian blue combines with this matter alone, without taking up any iron, as the solution of alkali does. It acquires a yellow or straw colour, and no longer manifests its alkaline qualities. It does not affect the test paper. It has lost its alkaline taste, and its attraction for carbonic acid. This compound, called the *prussiate of lime*, is a much finer test of the presence of iron, than the *lixivium sanguinis*, or *prussiate of potash*, because it contains no iron.

The union of this colouring matter with the various bases, is exceedingly weak; for every acid, even the carbonic, detaches it from them all. Nay, Scheele found that carbonic acid rendered blood incapable of imparting the colouring quality to the *lixivium sanguinis*. But, as observed by Dr. Black, the addition of a small quantity of iron, either pure or very slightly calcined, so fixes this acid in the *lixivium sanguinis*, that it now resists the action of any diluted acid. It is found, however, that strong sulphuric acid dissolves the blue precipitate, and forms with it a brown liquor,...but it becomes blue by diluting with water.

Mr. Berthollet has greatly augmented our knowledge of the prussic acid discovered by Scheele. He found that in Scheele's decomposition of the mercurial prussiate by means of iron, the iron took from it not only its prussic acid, but also its oxygen; for the iron was now an oxyd, and the mercury was revived.

His most curious observations related to the super-oxygenation of the prussic acid. He found that when mixed with oxygenated muriatic acid, it reduced the muriatic to its ordinary state, while the prussic had now acquired the abundant oxygen of the other, and its properties were greatly changed. It is now much more volatile: and, if exposed to the sun's light, it acquires the smell of aromatic oil, and even collects into a sluggish oil like liquor, heavier than water; and it is no longer

inflammable, nor precipitates iron. It is saturated with oxygen, which is equivalent to its being burnt already. In this oxygenated state, it does not form a blue, but a green precipitate, with the solution of vitriol. This is not owing to the mixture of a really blue precipitate with yellow oxyd of iron; for muriatic acid does not dissolve this oxyd, nor change the colour. It may be brought back from this state by sulphurous or volatile vitriolic acid. This is evidently by abstraction of part of the oxygen by the sulphurous acid. And, conformably with this account of it, we observe that the green precipitate mentioned just now, is made blue by the volatile vitriolic acid. The same effect is produced by exposure to the light. Now we know that in all cases of super-oxygenation, light detaches the redundant oxygen.

Scheele's preparation of Prussian alkali by means of sal ammoniac, chalk, alkali, and charcoal, shews that volatile alkali, or its component parts, hydrogen and azote, enter into the composition of the prussic acid. And if caustic fixed alkali or lime be mixed with oxygenated prussic acid, we have the vapours of caustic volatile alkali. Moreover, if the alkali or lime be now detached by sulphuric acid, we do not obtain the prussic acid again: it has been destroyed, and the volatile alkali just now mentioned has been part of it. But further, this addition of sulphuric acid produces effervescence of fixed air, or carbonic acid. This was not seen before. It would seem, therefore, that this is the other ingredient of the prussic acid; and that it consists of volatile alkali and fixed air, or of their component parts, hydrogen, azote, carbon and oxygen. Perhaps the last does not exist in it, but is furnished by the water in the distillation of prussic acid, and in that process combines with the carbon, forming the basis of carbonic acid.

After all the investigations of this eminent chemist, there is still a great uncertainty as to the real state of things in Prussian blue. I think that there may be strong objections made to the existence of any triple compounds in chemistry; and that all the examples offered are really mixtures of the third, with a true compound of the other two. Mr. Berthollet says, that there are two kinds of the prussiate of iron. One is the common Prussian blue, containing the iron or its oxyd, saturated with the tinging mat-

ter. The other consists of oxyd not saturated, or precipitate of iron with excess of oxyd. We obtain this by digesting an alkali on Prussian blue. It evidently takes to itself part of the colouring matter. But the remainder is not, as commonly thought, an ordinary oxyd; for when an acid is poured on it, we obtain Prussian blue. *

Alkali prepared in this manner, by digesting on Prussian blue by the assistance of heat, contains a considerable quantity of the second kind of precipitate. It will, by cooling for a considerable time, deposit this in form of a yellow calx. When thus freed from it evaporated to dryness, and then redissolved in water, it is called *purified Prussian alkali*. Mixture with vitriol produces no blue, if kept in the dark. But the light causes the blue precipitate to form gradually, till the whole alkali is decompounded.

[*Note 53. p. 183.*]

I forgot, when considering the solution of iron in the muriatic acid, to mention a curious observation of the Duke D'Ayen. When the martial muriat is exposed to a mild heat, water only slightly acidulated is disengaged;....then part of the acid rises, in almost incoercible fumes, but pure,....then a compound of the iron and acid rises, and condenses in elegant lancet-shaped crystals. When the more fixed matter which remains is urged by the most violent heat, there rises a vapour which seems truly metallic, condensing in regular hexagonal crystals, having the full opacity and lustre of polished steel, and strongly attracted by the loadstone.

This is unquestionably a volatilization of the metal: and I think points out some cementing processes, such as with common salt, which should make us expect valuable results. If this sublimate be a pure iron, it is surely in a state that we are not acquainted with. I should wish that in this process of the Duke D'Ayen, a magnet had been placed in the way of the vapours, or even applied externally by one of its poles, to the part of the receiver on which the sublimate appears to accumulate most speedily.

[*Note 54. p. 196.*]

These two remarkable masses of malleable iron mentioned in the text have greatly puzzled the naturalists who have attempted to account for them. Both were found so far from all traces of habitation, that there is no suspicion that they have been brought into that state by the operation of man. And indeed the appearance of the Siberian mass is such as could not have been induced by our greatest heats in our best furnaces. The whole has been in a state of most violent ebullition; there being many bladders in it larger than an egg; and the surface is all blistered. The whole is covered with a crust like iron-stone: but, internally, it is good red-short malleable iron. The mass found in South America is about fifteen tons weight, and of similar structure, but not so solid. This, and another of still larger size, and branched like a stumped tree, found in the same woods, three hundred miles from all appearances of iron, or even of stone, were lying on the surface of the earth. (*Phil. Trans.* 1788.) A mass of the same kind and appearance, near seven tons weight, was found under the pavement at Aken near Magdeburg, and is excellent iron.

In all those instances, it is remarkable that the fusion has been more complete than we can produce in our best furnaces. Also the glassy matter is transparent, and altogether unlike the slags which are formed in our metallurgic operations. No appearances of sulphurous admixture are observed in those masses.

Professor Chladni, an author of great respectability, is much disposed to think that all these masses have been portions of those fire-balls which are often observed to move in our atmosphere with immense velocity,...with a dazzling flashing light, frequently with smoke, making a rustling noise, and sometimes bursting in pieces with a loud explosion. The Siberian Tartars worship the lump above mentioned, as a thing come down from heaven. Many accounts have been given of red hot masses which have fallen through the air: and those which have been shewn as such, are all of the same kind, consisting chiefly of malleable iron. Chladni gives a

circumstantial account of three. One example at Hraschina, near Agram, in Hungary, is attested by many witnesses, before the Bishop's consistory at Agram. It was seen coming from a great distance, with a brandishing unequal light, like a long flaming chain: and it split into two pieces, which fell about a mile asunder, making holes *more than an ell wide*, and three fathoms deep. One weighed seventy-one, and the other sixteen pounds: and they are now in the Emperor's museum at Vienna. They are of the same kind exactly with those already described. That such trifling masses should make such excavations, can be accounted for, only by supposing them to be in a state of continual explosion or deflagration, blowing in all directions, like the instrument of destruction called a carcasse, discharged by a mortar. This will also give them a great apparent diameter while moving through the air. (*See Chladni's Dissertation on the Mass of Iron found in Siberia; Leipzig, 1794: and the Art of Mining and metallurgy, by Mr. Stultz, keeper of the mineral museum at Vienna, 1789. See also some valuable papers by Mr. Howard, in the Philosophical Transactions, 1802, &c. or extracts from them in Nicholson's Philosophical Journal*) In these papers every thing has been collected which has a relation to the subject: and Mr. Howard's observations are eminently ingenious and instructive.

[*Note 55. p. 209.*]

Dr. Black's notes contain no account of this process. I believe that it is not generally known: and although Jars has published what he calls the process carried on in Sheffield, we acquire little information from it. From the circumstance that the ores which afford a metal nearly in the state of steel, are generally spathose, or analogous to them, it seems not unlikely that the carbon which it wanted to form steel may be had in the fixed air. Accordingly, many of the old processes for case hardening iron, and for making small bits of steel, employ crude calcareous earth. The carburet (so plumbago is considered) burns very slowly. Perhaps even carbonic acid may be decomposed by iron, by the help of some double elective attraction. And the secret flux, of

which Mr. Jars speaks, may be a mixture containing limestone, and a proper re-agent.

[*Note 56. p. 224.*]

I confess that this appears to me to be an inaccurate, or at least an imperfect account of the matter. If indeed it relates only to the heat produced in the union of the nitrous and the vital air, to form nitrous acid, it is satisfactory. But if it be meant to explain the heat which is observed in the solution, when the gases are forming, it is surely inaccurate. Indeed this heat has always struck me as a very great difficulty in the whole theory. Mr. Lavoisier unquestionably derives his explanation of the heat produced in combustion from Dr. Black's theory of fluidity and vapour; and supposes that a gas consists of its radical, or distinguishing ingredient, combined with calorique, according to the ordinary laws of chemical affinity. This being supposed, the solution of metal in an acid, so far from producing or extricating calorique, should absorb it from the materials, and produce a cold incomparably more intense than any of our freezing mixtures. For such solutions, whether the metal be oxydated by the acid or the water, are always accompanied by the eruption of gaseous fumes. Iron in the diluted sulphuric acid produces an immense volume of gas. Those metals which are oxydated by decomposing the acid, produce gases which still contain much oxygen. And it may be remarked, that, in general, those solutions which produce fumes most deficient in oxygen, produce the greatest heats. This fact is favourable to Mr. Lavoisier's explanation. The oxygen remaining in its concrete form, does not expend any of the calorique extricated by other circumstances of the process. Supposing that no more latent heat is necessary than for the production of as much watery vapour as should have the same density, the quantity is very great, when compared with that which occasions the cold in our freezing mixtures. It must not be said that the quantity necessary for this gaseous combination may be small; for in this case, we should often have gases instead of ordinary vapours; whereas, we know that an incomparably greater supply of

calorique is required for the formation of a gas. Besides, the Lavoisierian theory of combustion supposes a vast accumulation of heat in oxygenous gas; this being, according to that celebrated philosopher, the source of all the heat extricated in that operation of nature. It must also be observed here, that the oxygenous gas gives out this heat; and the oxygen is combined with the inflammable body, in a state very similar to its condition in the present experiment. Therefore, we unquestionably have a prodigious quantity to account for; the oxygen in the dissolving or combining substances being unprovided in the quantity necessary for its becoming a source of heat in some future combustion.

I would now ask in what state is the calorique contained in the materials of an acid and a metal, when they act on each other? Some of the materials must contain it in a state that is unnecessary for their appearance in the state of a solution, of an oxyd, or of a metalline salt. When all this calorique has emerged, the oxygen in nitre still contains a great store of it, seeing that it is extricated from it in deflagration with inflammable substances. This only increases the difficulty. For this great store of calorique must remain in the solution, and in the metallic salt which it produces. Heat is extricated in the solution, and gas containing oxygen is produced. This gas, by uniting with vital air, again detaches calorique, and produces nitric acid. This acid will dissolve metal, and again detach calorique. This may be continued without end. This circumstance alone should convince us that there is some error in our theory; because this endless generation of heat is impossible in the nature of things. We cannot say, with any well grounded confidence, whether more calorique is extricated from oxygen, when, in the gaseous form, it causes the combustion of sulphur, or when, as an ingredient of nitre, it contributes to the deflagration with the same sulphur. I grant that I think that more is extricated in the first case. But it should be an immense deal more. For methods may be found for transferring the oxygen of the sulphuric acid, formed in the first case, to azote, and of thus forming nitric acid, and nitre, which will again deflagrate with sulphur.

All this is mysterious and intricate. I do not say incompatible; but I am not able to reconcile them by means of any known facts. The same, or greater difficulties, occur in almost all the spontaneous inflammations; in the deflagrations of nitrous acid with essential oils; and in many detonations; and in particular the heat and light which we call glow, or incandescence;....especially such as appears in the Dutch experiments, mentioned in page 335, on the mixture of sulphur with several metals. I acknowledge that I never was satisfied with the explanations given of this subject. Indeed it is rather kept out of sight by the French chemists. I am informed that Mr. Meunier, who was one of Mr. Lavoisier's chief assistants, tried many experiments, in company with Dr. Sommering of Mentz; and that they communicated their observations to Lavoisier and the chemists of Paris; and that these gentlemen were so little pleased with the results, that they were never mentioned in the Academy. I am disposed to assign a very different source of the heat in all these operations: and should this work have a second edition, I may probably have so far matured my ideas on the subject as to think them not unworthy of the public attention. At present they are by no means in such a state.

[Note 57. p. 229.]

The very ingenious Mr. Davy, chemical lecturer in the Royal Institution in London, has published, in *Nicholson's Philosophical Journal*, vol. III. p. 515. and vol. V. p. 281. the outlines of a chemical examination of this gas, which he very properly denominates NITROUS OXYD. He there mentions, in very general terms, its relations to heat, water, acids, alkalis, inflammable substances, &c. the methods of producing it, deduced from a due consideration of those relations, and the appearances of its compounds. This sketch is the performance of a sagacious observer and good reasoner.

With regard to its production, his experiments confirm Dr. Black's conjecture very clearly. He says that the most uniform and expeditious method of changing nitrous air into nitrous oxyd is to expose it to the action of a sulphite

of potash or soda. In an hour's time, 100 grains of dry sulphite of potash converts 16 cubic inches of nitrous air into eight inches of nitrous oxyd; and is itself partly changed into an ordinary sulphat.

But the method of preparing this oxyd, which he found the most convenient of all, was by means of nitrous ammoniac, mixed with thrice its weight of sand. This salt, the *nitrum flammans* of the older chemists, notwithstanding the singularity of its most obvious properties, has somehow escaped the pertinacious scrutiny of the chemists for a long while. Mr. Davy has made some very judicious experiments on it; and observed properties which are undoubtedly of great value, by the information they seem to give concerning the changes made on the affinities of chemical substances by a change of temperature. If nitrous ammoniac be kept steadily in a temperature very little exceeding 320 of Fahrenheit, it melts, and decomposes completely, resolving itself into water and the gas now under consideration. If raised much above 400°, and approaching to 500°, the constituent substances take other combinations, and produce the ordinary nitrous gas, and azotic gas, not combined. Probably, a very nice management of the heat might determine it either to the one or the other of those products, along with the water, which seems to form in every temperature, once the salt has melted. Should the temperature rise to 700°, another combination takes place; the oxygenous gas is decomposed; and we have a detonation. It must be remarked that the formation of nitrous gas and azotic gas is accompanied by a luminous appearance in the vessels. This is probably analogous to the low inflammation of phosphorus, sulphur, and other inflammable substances; and should induce us to examine those phenomena, to see whether they also are accompanied by such a change in their gaseous productions.

This is said to be the process employed by the society of chemists who have lately attracted so much notice by the employment of this gas for medicinal and dietetical purposes. Its effects, when breathed for some time, are very wonderful, and were first discovered, I believe by Mr. Davy. To those who are not hurt by the sight of folly, they are also very amusing.

Mr. Davy has also very ingeniously combined this gas with alkalis. He triturates a dry caustic alkali with a sulphite, and exposes the mixture to the action of nitrous gas. In this way the alkali acts on the nitrous oxyd, so as to combine with it in the very instant of its formation. He had found that the oxyd, already in a gaseous state, contracts no union with alkalis, if dry, and scarcely if in a watery solution. The compound tasted almost like a caustic alkali, but with a very peculiar pungency. The oxyd is expelled, in its genuine form, by any acid; also by a temperature exceeding 400°.

Inflammable substances decompose nitrous oxyd, much in the same way that they decompose nitrous acid: but the decomposition requires a much higher temperature. Sulphur burning slowly, with its weak blue flame, is extinguished in it. So are charcoal and phosphorus, if in their lowest temperature of combustion. But if any of those substances be made to burn briskly, producing a white light, they decompose nitrous oxyd with great rapidity, with an enlarged flame, and even deflagration. Therefore a candle burns with an enlarged flame, having a beautiful rose-coloured light. The sulphurous pyrophori burn vividly; but require a considerable heat to begin the combustion.

There is a peculiarity attending the burning in this gas. Nitrous acid is produced. Mr. Davy imagines that this arises from a new arrangement of principles, occasioned by the ignition of a *part* of the gas that is not immediately contiguous to the flame. He explains in the same way, some other phenomena which distinguish this gas from nitrous acid.

By comparing a variety of appearances, Mr. Davy concludes, that 100 parts of this oxyd consist of thirty-seven parts of oxygen, and sixty-three of azote, in a much denser state than that of their separate existence.

[*Note 58. p. 244.*]

Mr. Howard has communicated to the Royal Society of London a very curious account of a preparation of mercury, which explodes by a spark or an electrical shock, in the same

way as gunpowder, but with incomparably greater force, and with some peculiarities, which are remarkable and instructive. (*See Phil. Trans.* 1800. p. 204.)

The red oxyd of mercury was mixed with alcohol; and nitric acid was poured on it. It dissolved the oxyd before it acted remarkably on the alcohol; and after some time there was an ebullition, which sent forth a dense white smoke, smelling strongly of æther. The mixture deposited a precipitate, at first of a dark brown, and it gradually grew whiter. When separated by filtration, it appeared crystallized. Sulphuric acid was poured on this saline mass. A violent effervescence ensued; and the mixture exploded. When the sulphuric acid was much concentrated, the explosion often happened at the first contact.

Three or four grains of this salt in dry powder were laid on an anvil; and were struck with a smart blow with a hammer, in the manner practised by Fourcroy and Vauquelin with several salts. It detonated with great violence: and the faces of the anvil and hammer were very sensibly indented. The same effects were produced, by sending the shock of an electrical battery through five or six grains of it. The report of two grains is always as loud as that of a musket.

Two or three grains, lying in a sort of cup of tin-foil, were thus made to float on some oil. This was heated gradually: and the powder exploded when the temperature rose to 368°.

Mr. Howard then examined the explosive or expansive power of this substance when fired in the chamber of a piece, in the manner of gunpowder. It burst the barrel in which it was fired in a very extraordinary manner. Seventeen grains of it, however, were fired in the chamber of a fowling-piece, without destroying it. There was no recoil that was remarkable. The report was feeble; and the ball had about half the force which an ordinary charge, or 68 grains of the best gunpowder, would have given it. When the experiment was repeated with 34 grains, the barrel was destroyed, being torn into many pieces at the breech.

The expansive power of this substance was compared with that of gunpowder, by firing half an ounce of each in two

chambers, bored with the same tool, in two blocks of hard wood. The gunpowder split the block into three pieces, driving them from each other till the flame had room to escape. The mercurial powder burst its block in many directions, but without sensibly separating the fragments. The parts adjoining to the powder were pounded to dust.

A box of cast iron was made to fit exactly the chamber of a twelve-pound carronade. It had a cavity which held three and a half ounces of the mercurial powder. The box consisted of two parts, firmly screwed together. It was put into the carronade: and three twelve-pound balls were put above it. The powder was fired through a small touch-hole. The fore part of the box was blown out. The other part was shivered into many pieces; so were the two undermost balls; and the uppermost was cracked through the centre. The report was extremely feeble. The entire ball struck the mark with very little force.

Ten grains of the mercurial powder were fired by an electrical shock, in the centre of a glass ball seven inches in diameter, and half an inch thick. The glass withstood the shock; and its inside was coated with metallic mercury. Only four cubical inches of gas were found added to the air in the glass. They were a mixture of azote and carbonic acid. Ten grains of gunpowder were fired in the same manner: but no measure was taken of the gas. Indeed little could be inferred from the gases remaining when all is cold, because we are ignorant of what is absorbed. What is most remarkable in this experiment is, that the inflammation which takes place in this explosion, will not inflame gunpowder mixed with it in a loose state.

Mr. Howard ascribes the great force of the explosion to a greater rapidity of inflammation. He might have added, in all probability, a more complete inflammation; for some grains of the gunpowder were not inflamed. Indeed there is usually a very great portion that is driven out of the way without inflaming, when the powder lies loose, as in this case it did.

The most important circumstance in the experiment is the rapid diminution of the expansive force by an enlargement of bulk. It seems irresistible, while the particles of the gas

are very near each other ; but moderate, as soon as they have receded to a small distance. The effects of gunpowder agree very well with the supposition of a repulsive force between the particles, and acting only on the immediately adjoining particles, inversely proportional to their distance. The repulsion of the particles of this mercuriated gas must decrease much faster ; and may perhaps be as the square of the distance inversely. But be it what it will, it has a different law ; and therefore is a different gas from that of gunpowder, perhaps containing the vapour of mercury itself. There are experiments, by which it appears that this vapour is indeed very expansive. It may also have very little latent heat.

This dissertation is full of the most acute observations ; and contains a most ingenious analysis of the phenomena, and much chemical science.

[*Note 59. p. 245.*]

As this is the first example which we have, in Dr. Black's arrangement of the metals, of the separation of one metal by another, it may not be improper to pay a little more attention to the general phenomena.

The first observation I have to make on it is, that there is not such a violent effervescence accompanying the solution of the added metal, as when that metal is put into the pure acid. In some cases there is no effervescence whatever. And in every case the effervescence is extremely slight.

I may also observe, that the present example, the precipitation of mercury by copper, is the first fact appealed to by Dr. Stahl, as a strong argument for his doctrine of phlogiston. He appeals to it as a fact long and well known. There are many others equally distinct. Thus, lead dissolved by acetous acid is precipitated by zinc, in fine metalline crystals ; like sugar candy. Silver is precipitated from the nitrous acid by copper, also in metalline crystals. This precipitation forms a very beautiful object, when viewed through a microscope ; as it goes on in a drop of the solution, when a particle of copper is placed in contact with it. The crystals will be seen starting, as it were, into existence, or shooting out in fine ramifications.

According to the doctrine of Stahl, when a metal is dissolved in an acid, the acid is supposed to unite with the calx, and expel the phlogiston. Therefore, when an alkali is thrown into the solution, the precipitate must be conceived to be a calx, perhaps combined with a portion of the acid, or the alkali, or both. But when one metal is employed to precipitate the calx of another, the separation must be ascribed to the superior attraction of the acid for the calx of the added metal. For when this metal is dissolved in the pure acid, its phlogiston is supposed to escape. To abide by the example in the text, the acid must be supposed to have a stronger attraction for the calx of copper than for that of mercury. Therefore, when mercury is thus separated by copper, the phlogiston of the copper must be supposed to be expelled from the calx. It does not quit the mixture, but unites with the precipitated calx of mercury, and changes it into a metal.

Dr. Stahl accordingly asserted this double exchange ; and says that it is confirmed by the want of effervescence in most cases, and by the very faint effervescence in all. This small effervescence he accounts for in a manner sufficiently satisfactory, by saying that the precipitated metal did not require for its metallic form all the phlogiston which the acid expelled from the other.

Dr. Black, while he acquiesced in the doctrine of Stahl, did not content himself with a mere expression of this acquiescence; but was accustomed to exhibit this doctrine as not only plausible, but as extremely ingenious and elegant; and was at some pains to obviate the objections which were made to it. He saw clearly that it clashed with no principles of philosophy, to say that a substance might be positively light. And when I reminded him of the experiments on pendulums, by which Sir Isaac Newton proved that all sublunary matter is *equally* heavy, he considered these experiments with care, and thought that they were not susceptible of the accuracy necessary for deciding the question; because he observed that the exact determination of the centre of oscillation of such pendulums as Newton must have employed, was a thing which could scarcely be accomplished. It was this objection by Dr. Black which made me repeat Newton's

experiments, in a form where the position of the centre of oscillation is of no consequence. (*See Encycl. Britan. Supp. § Astronomy.*)

Impressed with this favourable notion of the doctrine of Stahl, Dr. Black was much offended by the contemptuous terms in which more than one or two French chemists, spoke of it,....calling it disgraceful to science, and what no man of common sense could adopt for a minute. He thought Stahl, Margraaf, Cramer, and other German chemists, by no means deficient in common sense; and used to say, that the French chemists forgot, in their dashing lessons to the rest of Europe, that Macquer, Geoffroi, Beaumé, were their countrymen. No man had a higher opinion of the genius, penetration, and sagacity of Mr. Lavoisier, than Dr. Black: and I have often heard him lament the loss which science sustained by his death. He admired particularly Lavoisier's quick sight of the importance of Mr. Cavendish's discovery of the composition of water, and his employing it immediately, not only to get over the difficulties which all the acids, except the nitrous, brought into view, but even to extend his doctrine far beyond the first conceptions of it. Dr. Black adopted all Lavoisier's doctrines: but he did not like the officious (as he called it) interference of some of his coadjutors: and he said that Berthollet was the only one of them in whose judgment and caution he had full confidence. With all this candour, he never would allow Stahl's doctrine to be spoken of in a slighting manner.

But to return from this eulogy on Stahl:....We must examine the manner in which the separation of one metal by means of another is explained in the doctrine of the French chemists. It is extremely easy, and pretty satisfactory: but it requires a little more thought and reflection to understand the whole internal procedure: and there are some cases in which there are difficulties which I do not think easily surmounted.

What is called the solution of a metal in an acid, is in general, rather the solution of a metallic oxyd: and we must regard this solution and the previous oxydation as two separate operations. When a metal is first oxydated, and then dissolved in an acid, we do not see where the one oper-

ation terminates, and the other begins; the one operation seems just the continuation of the other. If we attempt to resolve these questions by having recourse to attractions and repulsions and to conceive this succession of changes in a mechanical way, as is done by many who would be thought philosophical chemists, we shall find ourselves immediately put to a stand. For in mechanism, the law of continuity suffers no exceptions. But chemistry itself helps our conceptions of this matter, by shewing us other cases, where a similar succession of phenomena appears. Thus, the continued addition of heat to a substance shews us first the solid, then a fluid,...then a vapour. And in each of these changes of constitution and properties, there is a great absorption of heat. We have another example still more analogous. By gradually evaporating any brine, we at last produce crystals of salt, still consisting of the saline matter combined with water. Here the formation of a saline crystal, by the pure salt *first* attaching to itself the water of crystallization, which it certainly will do, if no more water be supplied to it, and then its subsequent solution in more water, are facts which very much resemble the formation of an oxyd, and its subsequent solution in more acid. Careful observation may discover many more examples of such a series, and it may be known as a very common phenomenon,...as a general though not universal law. But this is all the explanation that pure chemistry affords; and it is by a judicious observation and employment of such general laws, that it has become so comprehensive and important a department of natural knowledge.

Being more familiarly acquainted with the crystalline and briny forms of a salt, we seem a little entitled to reason from these to similar subjects which are less intimately known: and we are led to believe, that the oxygen which forms part of the oxyd, is more firmly united with the mercury, than what is afterwards combined with it as an ingredient of the acid. And this opinion is confirmed by observing, that in most cases, we can easily detach the acid; but that it is very difficult to detach the pure oxygen. In many cases, the most intense heat will not detach this last. Also, although we do not in the least understand why or how the

previous union of the oxygen with the azote of the nitrous acid should make its disposition to combine with the mercury any less, we know that this is a general fact in chemistry. And lastly, though ignorant of the efficient reason, we know that in proportion as more of an ingredient is already united with another, all subsequent additions are made with less force, and the union is less firm, or more easily destroyed.

Having these notions of the affinities of substances, we must suppose that the copper first attaches to itself as much oxygen as will render it an oxyd susceptible of union with the nitrous acid. This must certainly be taken from the mercurial nitrate, leaving the mercury still in the state of oxyd. It must therefore be taken from the nitrous acid in the mixture. This must be the order of procedure, because it is this portion of the oxygen that is easiest detached. The acid is already in the form of *nitrous acid*, having been decomposed in part when dissolving the mercury. Or, if we allow the acid of solution to be nitric acid, the first effect of the copper must still be to decompose some acid. The copper oxyd is at length formed: and now dissolves, by abstracting, not oxygen, but nitrous or nitric acid from the nitrate. This it continues to do more and more, reducing the mercury to the state of an oxyd, and last of all leaving it in its primitive form of a metal. This order of procedure is confirmed by observing, that in some cases the metal is left in the state of an oxyd, or in a state very little removed from it.

Now this procedure has, I think, considerable difficulties. We do not see, in any case, how the affinity of the copper for acid or oxygen, which continually diminishes as it attaches more to itself, is at last able to deprive the mercury of that portion of oxygen that is most strongly attached to it. We cannot suppose the oxydation of the mercury to be the first thing effected, being already persuaded that the copper, which can decompose pure acid, will more readily decompose it, when the combination of the parts of the acid is weakened by its union with the mercurial oxyd. It must therefore take the oxygen from the acid, and not from the oxyd: and the mercurial oxyd must be the last thing de-

composed. The firmest combination must be overcome by the smallest force.

Nor is it without its difficulties, to conceive how a metal becomes soluble in an acid, only by being already combined with one of its ingredients. I do not know any similar fact: and I have little confidence in any other mode of chemical investigation, and least of all in reasonings depending on the consideration of attractions and repulsions.

Farther, if the copper be oxydated by decomposing the nitric acid, we should have an effervescence of nitrous air as strong as when copper is put into pure acid. We cannot suppose that the redundant azote unites with the oxygen of the oxyd, and changes it into nitric or nitrous acid; because the mercury was oxydated by means of an affinity for oxygen, stronger than that of azote for the same oxygen. I think that this effervescence should be observed in every instance of separating one metal by means of another; even when the added metal is oxydated by decomposing the water. For I do not think that the redundant hydrogen will unite with the oxygen of the oxyd. Now these phenomena are not observed: what effervescence is observed is always weak. We have not inflammable air in all the cases where the added metal decomposes the water. In such cases we are led to think that the hydrogen is expended during the decomposition of the oxyd of the dissolved metal. But this also obliges us to suppose that the decomposition of one oxyd, and the formation of the other, are the first parts of the whole process, a thing which does not agree with our notions of the affinities.

I do not think it will be difficult to decide these questions by proper experiments: but none such have yet come in my way.

[*Note 60. p. 253.*]

As the notes found among Dr. Black's papers are not in such a condition that I can lay them before the reader, so as to answer the purposes mentioned in the lecture, I must content myself with giving the chemical arrangement of the medicinal preparations of mercury that was followed by him in his discourses,

with such of his observations on particular medicines as I thought might be of use.

Table of the preparations of Mercury, as drawn out by Dr. Black.

Hydrargyrus præparatur ad usus medicos:

I. Destillatione, ut purus fiat.

Hydrargyrus purificatus. Lond.

II. Triturâ, ut in atomos invisibiles attenuetur.

Merc. gummos. Plenckii.

Pilulæ Hydrargyri. Ed. et Lond.

Hydrargyrus cum cretâ. Lond.

Emplastrum Hydrargyri, sive cærul. Ed.

Emplastrum Lithargyri cum Hydrargyro. Lond.

Emplastrum ammoniaci cum Hydrargyro. Lond.

Unguentum Hydrargyri, sive cærul. Ed.

Unguentum Hydrargyri fortius et mitius. Lond.

III. Calcinatione ignis ope et aëris.

Hydrargyrus calcinatus. Lond.

Olim Mercurius præcipitatus per se.

IV. Viribus salium.

1. Cum acido vitriolico.

Hydrargyrus vitriolatus flavus, vulgo turpethum minerale. Ed.

Hydrargyrus vitriolatus. Lond.

2. Cum acido nitroso.

Guttæ albæ Wardi. (a)

(a) Dr. Black has given the following account of the process for preparing this medicine, known by the name of *Ward's white drop*:

A mixture being made of sixteen parts of pure aquafortis, and seven of volatile sal ammoniac, four parts of mercury are added for every sixteen of the mixture: and the mercury being dissolved, as much more is added as the liquor will dissolve.

This is evaporated till a pellicle just appears on the surface. It is now allowed to cool.

When cold, the heavy, uncrystallized, or fluid part, is drained off. The crystallized salt is dissolved in thrice its weight of rose water, which forms the white drop. The dose is in two drops, each dose containing half a grain of mercury.

Unguent um Hydrargiri nitrati. Ed. et Lond. (b)
 Hydrargyrus nitratus ruber. Ed. et Lond.

3. Cum acido muriatico.

Hydrargyrus muriatus corrosivus. Ed.
Hydrargyrus muriatus. Lond.
 Hydrargyrus muriatus mitis. Ed.
Calomelas. Lond.
 Hydrargyrus muriatus præcipitatus. Ed. }
Hydrargyrus Muriatus mitis. Lond. } (c)

4. Cum acido acetoso.

Hydrargyrus acetatus. Ed. et Lond.
Pilule Keyseri. (d)

(b) A variety of this ointment is used with success in the Manchester infirmary. It is prepared with the oil of butter, which has had no salt whatever. This preparation is found to preserve its colour unchanged.

(c) Dr. Black has written, on a copy of this table, an account of Scheele's process for this medicine, *viâ humidâ*, as follows:

Half a pound of mercury, and as much aquafortis, are put into a small matrass or cucurbit, having a pretty long neck. The mouth of it being covered with a bit of paper, a digesting sand-heat is given to the mixture for some hours. When the action of the acid becomes languid, the heat must be increased to nearly a boiling heat, and continued three or four hours,.... agitating the mixture from time to time. At last, make the solution boil gently, for a quarter of an hour; at the end of which there should remain a small quantity of mercury undissolved.

While the above is going on, dissolve four and a half ounces of pure sea salt, in six or eight pounds of water. Mix this solution, boiling hot, with the solution of mercury, also boiling,....stirring violently while they are mixed. Then allow the precipitate to settle; and afterwards edulcorate it with repeated washings of hot water,....and dry it. We obtain a *mercurius dulcis* in impalpable powder, amounting to eight and a half ounces.

The efficacy of this process is explained by Dr. Black, on the principles advanced in the lecture, namely, that the solution of mercury, made as here directed, is a sort of compound solution, containing a quantity of the metal, not oxydated, sufficient completely to saturate the muriatic acid. In proof of which, he says that this solution is precipitated black (a mark of crude mercury) by an alkali; whereas if the solution has been continued only till the cessation of effervescence, an alkali occasions a yellow precipitate, &c.

(d) Dr. Black refers for the preparation of this medicine to *Observ. de Medicine, de Mr. Richard, au Louvre, 1772*; and to the *Encyclopedie*.

5. Deturbatione ex acidis vi alkalinorum.

Hydrargyrus præcipitatus cinereus. Ed. }
Mercurius præcipitatus fuseus. } (e)

Calx Hydrargiri alba. Lond. (f)

Unguent. calcis Hydrargyri albæ. Lond.

V. Conjunctione cum sulphure.

Hydrargyrus sulphuratus niger. Ed.

Hydrargyrus cum sulphure. Lond.

Hydrargyrus sulphuratus ruber. Lond.

Pilulæ Hydrargyri muriati mitis, sive calomelanos, compositæ. Ed.

[Note 61. p. 262.]

Medicamenta parantur ex antimonio, vel sulphurato, vel sulphure privato.

Ex autimonio sulphurato.

I. Triturâ.

Antimonium præparatum. Ed. et Lond.

II. Ope ignis et aëris.

Flores Antimonii sine addito.

Vitrum antimonii. Ed.

Antimonium vitrificatum. Lond.

Vitrum antimonii ceratum. Ed.

III. Vi salis alkalini.

Hepar antimonii mitissimum.

Regulus antimonii medicinalis.

Hepar ad Kermes minerale *Geoffroi*.

(e) This, as prepared in the shops, is said to be frequently very acrimonious, which Dr. Black ascribes to impure aquafortis in the preparation.

(f) This white precipitate may be made exactly similar to calomel, by using plenty of volatile alkali for the precipitation, so much that the mixture may smell of it. This alkali will take from the metal a considerable quantity of the muriatic acid. Also by its hydrogen it deprives the quicksilver of the oxygen with which it was combined. The precipitate is therefore rendered insoluble in water, and scarcely soluble in vegetable acids. It will be very different if we are sparing of the alkali.

Dr. Black remarks in this note, that the fossil alkali, though aërated, cannot be made to precipitate mercury from a solution of corrosive sublimate, of a white colour, because the quantity of it which is sufficient for saturating the acid does not contain enough of air to saturate the mercurial precipitate, and render it white. He confirms this explanation by numbers, stating according to Mr. Kirwan's experiments, the quantity necessary for this purpose.

Hepar ad tincturam antimonii.

Kermes minerale.

Sulphur antimonii præcipitatum. Ed. et Lond.

IV. Vi nitri salis.

Crocus antimonii mitissimus.

Vulgo Regulus Antimonii medicinalis.

Crocus antimonii. Ed. et Lond.

Antimonii emeticum mitius. *Boerb.*

Antimonium ustum cum nitro, *vulgo* Calx antimonii nitrata. Ed.

Antimonium calcinatum. Lond. *Vulgo diaphoret.*

Antimonium calcareo-phosphoratum, sive Pulvis antimonialis. Ed.

Pulvis Antimonialis. Lond.

V. Viribus Acidorum.

Antimonium vitriolatum. *Klaunig.*

Antimonium catharticum. *Wilson.*

Antimonium muriatum, *vulgo* Butyrum antim. Ed.

Antimonium muriatum. Lond.

Pulvis Algerothi, sive *Mercurius vitæ.*

Bezoardicum minerale.

Antimonium tartarisatum, *vulgo* tartarus emeticus. Ed.

Antimonium tartarisatum. Lond.

Vinum antimonii tartarisati. Ed. et Lond.

Vinum antimonii. Lond.

Ex antimonio sulphure privato.

Hoc metallum, prout diversis modis liberatur a sulphure, dicitur Regulus antimonii simplex, Regulus antimonii martialis, Regulus Jovialis, &c. Ex eo parata sunt;

I. Ignis vi et æris.

Flores argentei, sive nix antimonii.

II. Vi nitri salis.

Cerussa antimonii.

Stomachicum. *Poterii.*

Antihecticum. *Poterii.*

Cardiacum. *Poterii.*

Medicamenta ab antimonio nomen mutuantia, quæ tamen ejus metalli vix quicquam retineat:

Cinabaris antimonii.

Tinctura antimonii.

[*Note 62. p. 300.*]

The grains of small shot made in this way are very often hollow, or have a deep pit in one side, which is frequently rugged within, it is owing to the sudden congelation of the outside by the water. This forms a hard case, while the interior is still fluid; and, contracting as it cools, a part is left empty. As this greatly hurts the value of the small shot, many attempts have been made to prevent it, which have been more or less successful. Some manufacturers have mixed other metals with the lead,....others have kept oil on the water,....others receive the lead into boiling hot water covered with melted tallow. I believe that the most successful method has been that of the patent shot manufacture in Southwark, London, where the furnace is at the top of a very high tower, not less than one hundred feet, and the shot is gradually cooled as it falls through the air. The chief effect of this, however, must be the incomparably greater number of spherical grains. I do not see how this will much prevent the hollowness of the shot, even although the tower were four times as high. The shot would fall two hundred and fifty feet in four seconds, and four hundred feet in five seconds, neither of which would sufficiently cool it. Its latent heat requires a much longer time than this for its absorption by air. The pear-like shape is occasioned by the fluid lead within breaking through the crust, and freezing as it comes in contact with the water. Metals afford very curious forms, by dropping them when fluid into water. When this is done from a very small height, the drops descend slowly through the water. The fluid within breaking the crust by its great weight, runs out, freezing as it goes down, and often leaves a pretty round thin cup with a taper thing below it like an extinguisher. Some metals thus form themselves into nails with large heads,.... others take other shapes, very uniform, and very unexpected. Great differences are produced by different liquors instead of water, and by different heats of the metals, and by the heights from which they are poured, &c.

[*Note 63. p. 332.*]

It is by no means clear that the acid has increased its proportion of oxygen by deoxygenating the copper. It is true that the copper remaining in the retort scarcely needs any addition of inflammable matter to reduce it: but there is adhering to it a large proportion of extractive coaly matter, which answers the same purpose: and the fact is, that when this is urged by a strong heat, we obtain a great deal of fixed air. Of this I have had repeated experience. It is indifferent whether this be conceived as composed of the oxygen of the cupreous oxyd or from the acid. In neither case can the acid be said to have increased its proportion of oxygen in any other way than by leaving behind a portion of carbon. I see nothing that induces me to think even this to be the case, or that there is not as much oxygen taken from the acid in this operation as belongs to the extractive or carbonic matter. Mr. Chaptal (*Ann. de Chymie*, vol. 28.) thinks that he sees plain differences between what he chooses to call acetous and acetic acid. But they appear to me very unsatisfactory. The superior acidity of the acid obtained by the present process is sufficiently accounted for by its dephlegmation and freedom from mucilaginous and other extractive matter. At any rate, this is by no means the most eligible process for obtaining from this salt the greatest quantity of acetous or acetic acid, free from empyreuma: and, as Dr. Black has not mentioned any of the other methods of decomposing it, I trust that the reader will not be displeased with some account of the most approved of them.

The simplest and most obvious of all is to employ the superior affinity of another acid; and of these the most fixed is to be preferred. Concentrated sulphuric acid being poured on the acetite of copper, it detaches the acid with great facility, and as agreeably fragrant as the *best* of the dry process, or what comes over after the portion tinged with the copper, and before any empyreuma can be observed. It is also extremely strong, and of a pungent odour: and the last portion is inflammable. This was first observed, I think, by Count de Lauragais: and he employed it to form an acetic æther, which exceeds others in fragrance. There is generally some carbonated matter left

adhering to the sulphat: and this has been adduced as a proof that the acetic acid, by depositing carbon, has become redundant in oxygen.

It will be said that the acid obtained by this process is not in a state of complete dephlegmation, as in the other. But I may observe here, that the other process cannot be easily conducted without some water. Without this addition, in order to transmit the heat more readily to the centre of the mass, the acid cannot be expelled from thence, without over-heating the exterior parts.

A still better process is that of Mr. Lowitz. He mixes three parts of the acetite of copper with eight parts of a sulphat of potash surcharged with acid, (prepared by distilling sulphuric acid from potash, to dryness). This mixture, in dry powder, contains as much redundant sulphuric acid as is sufficient for saturating the copper or its oxyd, and for extricating the whole of the acetous acid, with a very moderate heat. He affirms that in this way we obtain it, with all the fragrance possible, from this preparation.

Nitric, or the oxygenated muriatic acid, or aqua regia, might be employed, with proper precautions, to decompose the cupreous acetite, and seem the fittest for enabling us to judge whether the acetous acid can be superoxygenated.

[*Note 64. p. 357.*]

I must not omit this opportunity of making some remarks on this mode of concretion of the silver. It must happen in consequence of an attraction which brings together, in a certain determinate manner, the minute atoms into which the silver is divided. The same thing is observable in numberless instances of precipitation; and is probably universal. Often, indeed, the precipitate is a fine impalpable powder. But each particle of this is a mountain, in comparison of the atoms in their state of separation, while chemically united with those of the solvent. Often are we able to see with a microscope, that each of these particles of powder is a group of minute regular forms or crystals. Nay, even when the precipitate is gelatinous, as in luna

cornea, I am persuaded that its structure is not uniform, but plated or symmetrical. This I conclude, from observing that the formation of such jellies proceeds in a way which resembles the more sensible crystallizations. When a solution is just ready to shoot into crystals, if we touch it with a particle of the crystal, the change begins there, and spreads from it as a centre. I observe the same thing in the formation of some gelatinous concretions by inspissation. But, to return to this precipitation of silver;....it is particularly to be remarked, that, although the concretion proceed, from a basis sending out stems, from which proceed branches, which again produce subordinate ramifications, and the concretion has therefore been called a vegetation, it does not at all proceed in the manner of a growth, or a gradual protrusion from a parent trunk. This trunk does not grow or change at the same time. Nor does it appear to contribute any thing whatever to the increase or ramification. It remains of the same length: the same distance remains between every branch: and all the increment is plainly an accretion of external matter applied to its extremities, or to different parts of its surface in succession. The additions are of matter previously floating about. The little shrub, therefore, is not produced by the gradual developement of a seminal body nor by the action of its organical structure on the fluid matter which it pumps along its canals, assimilating it as it goes along, and secreting or rejecting it according to fixed laws. In the present case, every atom seems to have the same powers, and to be equally capable of becoming either the stem or any one of the branches. When we observe the gradual formation with attention, assisted by a microscope, we observe each little addition to start into existence in a moment: and we can scarcely tell when or where to expect the next. They are all *accretions*,....*appositions*, of silver previously floating about in the solution. Sometimes, indeed, a little branch employs a sensible moment in attaining its full length: but even then, I presume, that this is a succession of many instantaneously formed plates; for we know that *all* crystals are of a transversely plated structure. I cannot but think that the atoms of silver continue to be suspended, or to float about for some little time, after their separation from the

acid, in their individual and invisible form ; and that they are thus carried to some distance from the copper (*in contact of which only* they are detached from the acid) before they arrange themselves in some little symmetrical group, fitted to form a new crystal, observing such a law of attraction, that it must attach to those already formed, in one way, but not in another. Or, shall we say that there is a power resembling magnetism, electricity, or galvanism, propagated from the central bit of copper? This last (galvanism) seems to offer the best means for *illustrating* the phenomenon: for it cannot be called an explanation; but it is of the same kind with all other explanations purely chemical. None of them aim at ascertaining the proximate cause, and its manner of action. It is thought a sufficient explanation, if we shew that the phenomenon is one of a great class already known, although we are equally in the dark with respect to each of them. The philosophical chemist, indeed, frequently attempts something more and to shew *how* the chemical attractions operate in producing the phenomenon. This is precisely the difficulty here. The question is not chemical, but mechanical. We are required to shew how certain centripetal, or centrifugal forces separate certain particles, and bring them together again in another determinate manner. The chemist ascertains, from observation, the affinity, that is, the cases in which such separations and reunions are invariably effected. When he goes further, and speaks of his greater and smaller attractions, of one attraction opposing another, &c. he speaks as a mechanician, and generally without any distinct conceptions of the subject. In questions of this kind, the object before the mind is an atom of *moveable matter*, under the influence of a *moving force*: and all discussion must now proceed on the acknowledged laws of motion. I take it that the present phenomenon is one of those which sets the insufficiency of those usual modes of reasoning in the clearest light. I cannot conceive any action between the copper and the *adjoining* acid, which can produce the deposition of a *remote* atom of silver from a *remote* atom of acid, which will not be produced by the action of the already formed solid silver, adjoining to that particle of acid which deposits its silver. All that I can do, is to recollect that something very like it hap-

pens when I bring a magnet near a parcel of iron-filings, which were lying confused, and without any mutual influence. Every individual rag of iron becomes in an instant active; turns about; and presents one extremity to one adjoining rag of iron and the other to another. They adhere together; and when I draw one away, it drags another after it, &c. And all this activity is at an end, whenever I remove the magnet. Here then is a considerable resemblance of effect: but it is still very imperfect. The mere presence of the copper is not enough: it must be in the very act of dissolving in the *contiguous* acid. The galvanic phenomena have a much closer resemblance to what we are now considering. Indeed they are almost the same. We have at one wire an oxydation going on; and a deoxydation going on at the other: and the two have an invariable dependence on each other. The one cannot happen unless the other also happen: and we cannot tell which is the prior event. But this is only an illustration: and the immediate actors and powers remain as much unknown as ever. Can the phenomenon be conceived in this way? It is probable that an unsaturated solution of copper, and a saturated solution of silver in the same acid, may remain mixed together without changing. We know this to be true with saturated solutions of silver and mercury. When copper is put into such a mixture, it *may be* that a greater dose of it being acquired by the acid in contact with it, liberates some silver, (though I cannot tell how) which liberated silver floats off; and is carried by the fluid till it meets with a crystal of silver already formed, acting with polar forces, like the particles of iron-filings; and there it settles symmetrically.

It is to be wished that chemists would endeavour to acquire some more precise notions than they seem to content themselves with at present, of those internal procedures. Such unbounded use is made of the change of partners (so to express myself) between oxygen, hydrogen, azote, and carbon, in the chemical phenomena of vegetable and animal substances, that every tyro from the chemical classes finds himself in a condition to write a system of chemistry, which leaves nothing unexplained, and admits of no contradiction. The author of a *Pyrologia*, by

bringing caloric into the chemical dance, finds himself qualified to make a world. It is time to check such unprofitable speculations. Dr. Black's maxim of setting one foot firm on ground which we know familiarly, before we attempt to make another step, is the only safe way of proceeding in this noble but difficult science. An example, still more remarkable and puzzling, occurred to me very lately. I had set up a galvanic pile, of 420 pairs of silver and zinc plates, having pieces of woollen cloth soaked in a saturated solution of sea salt. It stood on a table in a warm room; and the evening sun shone on it. Chancing to look at it from the other side of the room, I observed a most beautiful nimbus or glory surrounding a great part of the column, exhibiting fine prismatic colours. I went immediately to take a nearer view of it, and it vanished. Returning to my chair, I saw it again, but not if I moved my head much to either side. I went to it again, and viewing it with a reading glass, I observed that each piece of cloth had, all around, fine crystals standing out almost horizontally. They were more slender than the finest human hair; and many of them (no thicker than the rest) were two inches long. They were perfectly straight, except a small bending by their own weight. I could perceive, by their manner of reflecting the light, that they were angular prisms, and that they were jointed transversely, like the *equisetum lacustre*.

Now I would ask how these crystals of soda (for such they are) were formed? I let some fibres of cotton fall on them; and could observe that the part *beyond* the fibre increased, without the fibre itself being carried farther from the soaked cloth by an increase of what was between them.....It is very mysterious.

[Note 65. p. 371.]

When we reflect on the manner in which it explodes, when lying loose on a plate of metal, where it is perfectly open to expand upwards and laterally, and on the very small portion of this small quantity of matter that is hindered from expanding downwards, and on the impression that it makes, it gives us some notion of the immense velocity with which it expands. I

found that seven grains, lying on a plate of brass, and exploding by heat, made as great an impression as a piece of iron, two and a half pounds weight, falling on it with the velocity of 25 feet in a second. We cannot compute the downward action at more than one-fourth of the whole expansion. We must therefore calculate the velocity of $1\frac{3}{4}$ grains which will give as great a blow as the piece of iron, which weighed 17,500 grains. We shall find this velocity to be 250,000 feet, which is nearly 45 miles, in a second. Yet this is probably very small in comparison with the velocity of expansion of the fulminating silver, perhaps not the 100th part of it. Thus we approach to some of those astonishing forces that operate in the emission and refraction of light, and many other phenomena of nature.

[Note 66. p. 395.]

No observations, made with any immediate purpose of employing them in the lecture, are to be found among Dr. Black's papers, on several substances which seem to be pretty generally admitted as metallic; namely, those called *molybdenum*, *tellurium*, *chromum*, *tungsten*, *uranium*, *titanium*, &c. It appears that he did not consider the very imperfect knowledge acquired of them as of importance enough to occupy any of the time allotted for course of elementary instruction in the *science* of chemistry. The few distinguishing properties established with respect to each of them are not such as have any extensive influence, either on doctrinal points, or the conduct of chemical processes, or the improvement of the chemical arts. Some of them, particularly the one called titanium, seems to have engaged his attention a good deal. But the state of his health precluded all labour on his part to acquire a more perfect knowledge of its properties.

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